NUWC-NPT Technical Document 10,863
3 May 1995

Dynamic Measurements of Three Urethane Hose Materials

Robert A. Lafreniere
Engineering and Technical Services Department

Roger Tryon
McLaughlin Research Corporation

Naval Undersea Warfare Center Division
Newport, Rhode Island

Approved for public release; distribution is unlimited.

PREFACE

The document was prepared for the Johns Hopkins University, Applied Physics Laboratory (APL) under task no. 11S51ZZTZ9ZT19ZZZZST1Z54010PZ of the Navy Prime Contract N00039-94-C-0001. The APL program sponsor is Charles W. Kennedy.

The technical reviewer for this report was Dr. R. Munn (Code 42).

Reviewed and Approved: 3 May 1995

Russell L Brown

R. L. Brown
Head, Engineering and Technical Services Department

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave Blank)

2. REPORT DATE
3 May 1995

3. REPORT TYPE AND DATES COVERED
Final

4. TITLE AND SUBTITLE
Dynamic Measurements of Three Urethane Hose Materials

5. FUNDING NUMBERS
PR A96645

6. AUTHOR(S)
R. A. Lafreniere and R. Tryon (McLaughlin Research Corp.)

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Naval Undersea Warfare Center Detachment
39 Smith Street
New London, Connecticut 06320-5594

8. PERFORMING ORGANIZATION REPORT NUMBER
TD 10,863

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Naval Undersea Warfare Center Division
1176 Howell Street
Newport, Rhode Island 02841-5594

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

This technical document reports the test results of dynamic tests performed using a Metravib Visco-analyseur Machine on three urethane hose materials (Dow 2103-80A3 Pellethane, Dow 2351-85AE Pellethane, and B. F. Goodrich 58315 Estane). The materials were supplied by the Johns Hopkins University Applied Physics Laboratory. Dynamic measurements were made over a temperature range of -40 to +40°C and a frequency range of 5 to 500 Hz. Mechanically-measured transitions were observed and were all approximately 0°C.

In an attempt to collect directly-measured data to 1000 Hz, the measured test data above 500 Hz was observed to contain data scatter which was deemed questionable and, thus, considered unreliable. The maximum frequency of the data determined reliable was limited to 500 Hz. To extrapolate data beyond the directly-measurable frequency range, a Williams, Landel and Ferry (WLF) frequency/temperature shift was performed. The shifted data extends well beyond the desired frequency of 1000 Hz.

An additional test was performed on a Differential Scanning Calorimeter to determine the glass transition temperature (T_g). The T_g was determined for the materials as approximately 30 to 40°C below the mechanically-measured transitions.

14. SUBJECT TERMS
Dynamic Measurements
Urethane Hose

15. NUMBER OF PAGES
126

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	SAR

NSN 7540-01-280-5500

Standard Form 298 (Rev 2-89)
Prescribed by ANSI Std Z39-18
298-102

EXECUTIVE SUMMARY

This technical document reports the results of dynamic tests performed using a Metravib Viscoanalyseur Machine on three urethane hose materials identified as Dow 2103-80AE Pellethane, Dow 2351-85AE Pellethane, and B. F. Goodrich 58315 Estane. A flat sheet of the 2103-80AE Pellethane material (approximately 5 inches (12.7 cm) wide by 5 inches (12.7 cm) long) was supplied for testing along with a 1-foot (30.5 cm) long hose section of the other two materials. The Johns Hopkins University, Applied Physics Laboratory (APL), supplied the materials to the Materials Laboratory of the Experimental Measurements and Materials Technology Section (Code 4211), Naval Undersea Warfare Center Division, Detachment New London.

Dynamic measurements were made over a temperature range of -40 to +40°C and with a frequency range of 5 to 500 Hz. Several tests were conducted for each material to acquire acceptable data within the measurable ranges of the Metravib Viscoanalyseur Machine. Mechanically-measured transitions were observed as follows:

Material	Mechanically-Measured Transition (°C)
2103-80AE Pellethane	-5
2351-85AE Pellethane	5
58315 Estane	-5

For each of the three materials considered, the measured test data above 500 Hz were observed to contain data scatter. Due to the amount of scatter, the data were deemed questionable and, therefore, considered unreliable. The maximum frequency of the data determined reliable was limited to 500 Hz. To extend (extrapolate) the data beyond the directly-measurable frequency range (5 to 500 Hz), a Williams, Landel and Ferry (WLF) frequency/ temperature shift was performed. The shifted data extended well beyond the desired frequency of 1 kHz with room temperature as the reference temperature.

An additional test was performed on a Differential Scanning Calorimeter (DSC) by the Chemistry Laboratory (T. Ramotowski), Transduction Exploratory and Advanced Development Branch (Code 2131). The purpose of the additional testing was to determine the glass transition (T_g) temperature. This additional testing was necessary because WLF shift requirements state that the shift can be performed in the range of T_g and T_g plus 100°C. The T_g was determined for the materials as follows:

Material	DSC-Determined T_g Temperatures (°C)
2103-80AE Pellethane	-46
2351-85AE Pellethane	-25
58315 Estane	-46

It was determined from these values that, if necessary, all mechanically-measured data from these tests may be shifted.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

DYNAMIC MEASUREMENTS OF THREE URETHANE HOSE MATERIALS

INTRODUCTION

The Johns Hopkins University, Applied Physics Laboratory (APL), provided several material samples to the Materials Laboratory of the Experimental Measurements and Materials Technology Section (Code 4211) of the Naval Undersea Warfare Center Division, Detachment New London.. These specimens were provided for dynamic testing in an effort to establish dynamic mechanical properties over a temperature range of -20°C to +40°C and a frequency range of 5 Hz to 1 kHz. After several attempts to acquire data to 1 kHz, with test results comprised of scatter above 500 Hz, the effort was abandoned. Due to the scattered data points above 500 Hz, the data were considered unreliable and, therefore, not used. To obtain the necessary data at 1 kHz, a Williams, Landel and Ferry (WLF) frequency/temperature shift was performed to allow extrapolation of the dynamic properties at higher-than-measured frequencies.

Three materials were provided by APL. The first, Dow 2103-80AE Pellethane, was provided as a 5-inch (12.7-cm) by 5-inch (12.7-cm) flat sheet. The second two materials were provided as 1-foot (30.5-cm) long by 3.5-inch (8.9-cm) diameter hose sections. Test specimens were cut from the furnished material.

Dynamic measurements were obtained in the tension mode on a Metravib Viscoanalyseur Machine. This instrument has the capability to sweep through a range of user-preset frequencies and a wide range of temperatures. Tension testing was conducted on a parallelepiped configuration.

All dynamic measurements were obtained under the same conditions. The test specimen was set up under room-temperature conditions (22°C, 50 percent relative humidity), then brought down to the first temperature step of -40°C where the specimen went through a 15-minute dwell time to reach thermal equilibrium. A similar dwell is used at every temperature step. This process was used through a temperature range of -40 to +40°C in 10°-increments. At each step, the instrument goes through a frequency sweep from 5 to 500 Hz in 50-Hz increments with a 1-minute dwell between each frequency to allow the specimen to stabilize. The data are presented in different graphical formats with Appendices containing the associated tabular data.

In addition to dynamic testing, a Differential Scanning Calorimeter (DSC) test was performed by the Chemistry Laboratory (T. Ramotowski) of the Transduction Exploratory and Advanced Development Branch (Code 2131). This test locates the glass transition (T_g) temperature, which is a necessary quantity for the WLF superposition technique implemented to obtain the 1 kHz parameter of the test.

DYNAMIC TESTING

All of the dynamic tests for this document were conducted on a Metravib Viscoanalyseur. The Metravib Viscoanalyseur applies a fixed displacement to the specimen and records either the force/displacement or the force/acceleration relationship. This displacement is represented by

$$x(t) = X\sin(\omega t), \tag{1}$$

where x is displacement as a function of time, X is the magnitude of displacement, ω is the driving frequency, and t is time. Based on the measured relationship, the dynamic material properties of the specimen are determined. Prior to testing, a calibration run was conducted that indicated the instrument was within calibration specifications established by the manufacturer.

For tension/compression testing, parallelepiped specimens were prepared, measured, and bonded to platens (using cyanoacrylate adhesive) which were installed in the Metravib Visco-analyseur. A suitable amount of time was allowed for the adhesive to cure; then, the test was performed.

A sample property of the test specimen to which the Metravib Viscoanalyseur is sensitive is the shape factor,s. The shape factor is defined as the excited cross-sectional area of the specimen divided by the free surface area of the specimen, i.e.,

$$s = \frac{wt}{2h(w+t)}. \tag{2}$$

where s is the shape factor, w is width, h is the height, and t is thickness. As the shape factor, s, approaches zero, the test becomes more reliable. The implication of the shape factor is that for a long, slender specimen, the modulus can be directly determined (i.e., the shape factor is small). For a short, fat specimen, the modulus must be corrected within the Metravib software package. Based on the dimensions of the specimen, the following relationship is desirable:

$$w * t << 2 * h * (w + t). \tag{3}$$

The specimen dimensions for each material tested are listed in the associated Appendices. The first material, Dow 2103-80AE Pellethane, was tested three times in an attempt to minimize the shape factor. The first test was conducted at a ratio of 1:6. The measured stiffness, however, was not high enough to achieve reliable results. The second test involved decreasing the specimen height by a factor of 2, yielding a shape factor of approximately 1:3; this test also proved to be too soft. On the third trial, the specimen height was again decreased and the measured stiffness was sufficient for dependable results (shape factor of 1:2). All of the measured data were above the minimum-recommended stiffness. This was not the optimal shape factor, however, due to the low modulus and the thickness of the material. The shape factor was necessary to obtain a stiffness within measurable limits of the Metravib. For this material, a thicker sheet would have provided data with a more desirable shape factor.

The test results are reported as a series of figures with associated tabular data. Figures 1 through 4 depict the dynamic test results of the Dow 2103-80AE Pellethane. Figure 1 depicts the real component of Young's Modulus (E') and the loss tangent (tan δ) versus temperature.

Plotting data in this manner allows for rapid visualization of transitions. In this graph (figure 1), a transition is evident at approximately -5°C. Figure 2 depicts E' and tan δ versus frequency. Figure 3 depicts the imaginary component (E") of Young's Modulus along with the complex modulus (E*) versus frequency. Figure 4 is a Wicket plot for this series of measurements. A Wicket plot is a log-to-log graph depicting tan δ versus E'. When a dynamic test is performed, the resulting data, plotted in this manner, will result in an inverted horseshoe shape if the tested temperature range passes through a transition. The smoother the curve shape, the better the measurements and the greater the accuracy. As is evident in figure 4, the shape indicates a good test. This figure includes all data points recorded, which were all within the reliable range of the Metravib Viscoanalyseur, as is evident in the 2103-80AE Pellethane Cut-Off Frequency Table (table 1). The table lists the highest frequency at which acceptable measurements were obtained. Tabular data for this test is included in Appendix A.

Table 1. Cut-Off Frequencies for 2103 Pellethane

Temperature (°C)	Tension
-40	500
-30	500
-20	500
-10	500
0	500
10	500
20	500
30	500
40	500

In order to extrapolate the measured data beyond 500 Hz, a WLF shift was performed to achieve the resultant ability to extrapolate the dynamic properties at higher-than-measured frequencies. This shifting technique allows the development of a master curve, which is the superposition of one isothermal (constant temperature) curve onto another at a selected reference temperature (T_O). A shift factor (α_T) is determined for each set of data, which allows the frequencies to be shifted relative to T_O. In this case, the Metravib Viscoanalyseur has a software package that performs the shift and calculates a master curve from a previously-measured set of data. For more information regarding WLF superposition, consult references 1, 2, and 3.

In these references, one requirement for an accurate WLF shift is that it must be performed in a range of T_g to T_g plus 100°C. The DSC test (Appendix B) yielded a T_g value of -46°C which indicates test data up to 40°C is acceptable in the shift. It should be noted that the T_g value from this test will not be the same as that of the transition observed in the Metravib test. Reasons for the two machines having different transitions are explained in Appendix B.

The results of the Young's Modulus shift are presented in figure 5. By establishing 20°C as a reference temperature and using five temperatures, a frequency of approximately 50 kHz was achieved. Figure 6 is the WLF shift on the tan δ. This shift obtained frequencies to the same range. It should be noted that there is some data point scatter in the curves; these points are not used in the shift. Tabular data, along with shift factors, are included in Appendices C and D.

When setting up and running the Dow 2351-85AE Pellethane, shape factors were a concern as in the previous test. Since the wall thickness of the supplied hose specimen was approximately twice the thickness of the previous (2103-80AE) material, the shape factor was improved. This specimen required three experiments also to attain test parameters within measurable range. The first test had a shape factor of 1:5.64; but, the machine ran out of liquid nitrogen and the data were discarded. The second test required cutting the specimen height down by 0.41 millimeter to obtain the shape factor of 1:5.06 and attempt a run to 1 kHz. This test was comprised of too much scatter, however, and the stiffness still too low. The third test, with a shape ratio of 1:4.23, was run to 500 Hz. This shape factor, along with the increase in stiffness, generated an acceptable test while using the same test parameters as in the previous test.

Figures 7 through 10 present the data from this series of tension tests. Figure 7 depicts E' and tan δ versus temperature. In this graph, a transition is evident at approximately +5°C. Figure 8 depicts E' and tan δ versus frequency. Figure 9 depicts E" along with E* versus frequency. Figure 10 is the Wicket plot for this series of data points. As seen in the Wicket plot, the shape is evident and indicates a good test.

Stiffness ranges were examined and recorded as within measurable range. These data points are listed in table 2 (2351-85AE Cut-Off Frequencies). Appendix E includes the tabular data for this test. As noted in Appendix B, the glass transition for this material is approximately -25°C which indicates that all data in this measurement may be used in the WLF shift.

Table 2. Cut-Off Frequencies for 2351-85AE Pellethane

Temperature (°C)	Tension
-40	500
-30	500
-20	500
-10	500
0	500
10	500
20	500
30	500
40	500

Figures 11 and 12 are the master curves depicting E' and tan δ, respectively, as a function of Frequency. These two curves almost reach 6.5 kHz while using 20°C as a reference temperature and four temperatures for shifting. Tabular data and the associated shift factors are included in Appendices F and G.

For the 58315 Estane material, the shape factor was set at 1:5.8 for the first test and provided acceptable data. With this shape factor, the specimen was too soft at the higher temperatures; these data points are noted in the associated graphs and tables. The 58315 Estane material was tested using the same parameters as those of the two previous tests. Figures 13

through 16 contain the associated graphs. Figure 13 depicts E' and tan δ versus temperature. In this graph, a transition is evident at approximately -5°C. Figure 14 depicts E' and tan δ versus frequency. Figure 15 depicts E" along with E* versus frequency. Figure 16 is the Wicket plot for this series of data points. Although there is some data scatter on the high-temperature end, this plot indicates a good test. Table 3 depicts the last acceptable frequency. Appendix H contains associated tabular data.

Table 3. Cut-Off Frequencies for 58315 Estane

Temperature (°C)	Tension
-40	500
-30	500
-20	500
-10	500
0	500
10	500
20	451.3
30	451.3
40	400.6

As noted in Appendix B, the glass transition for this material is approximately -46°C which indicates that all data in this measurement may be used in the WLF shift.

Figures 17 and 18 are the master curves depicting E' and tan δ, respectively, as a function of frequency. These two curves reach approximately 6.6 kHz. Tabular data and associated shift factors are included in Appendices I and J.

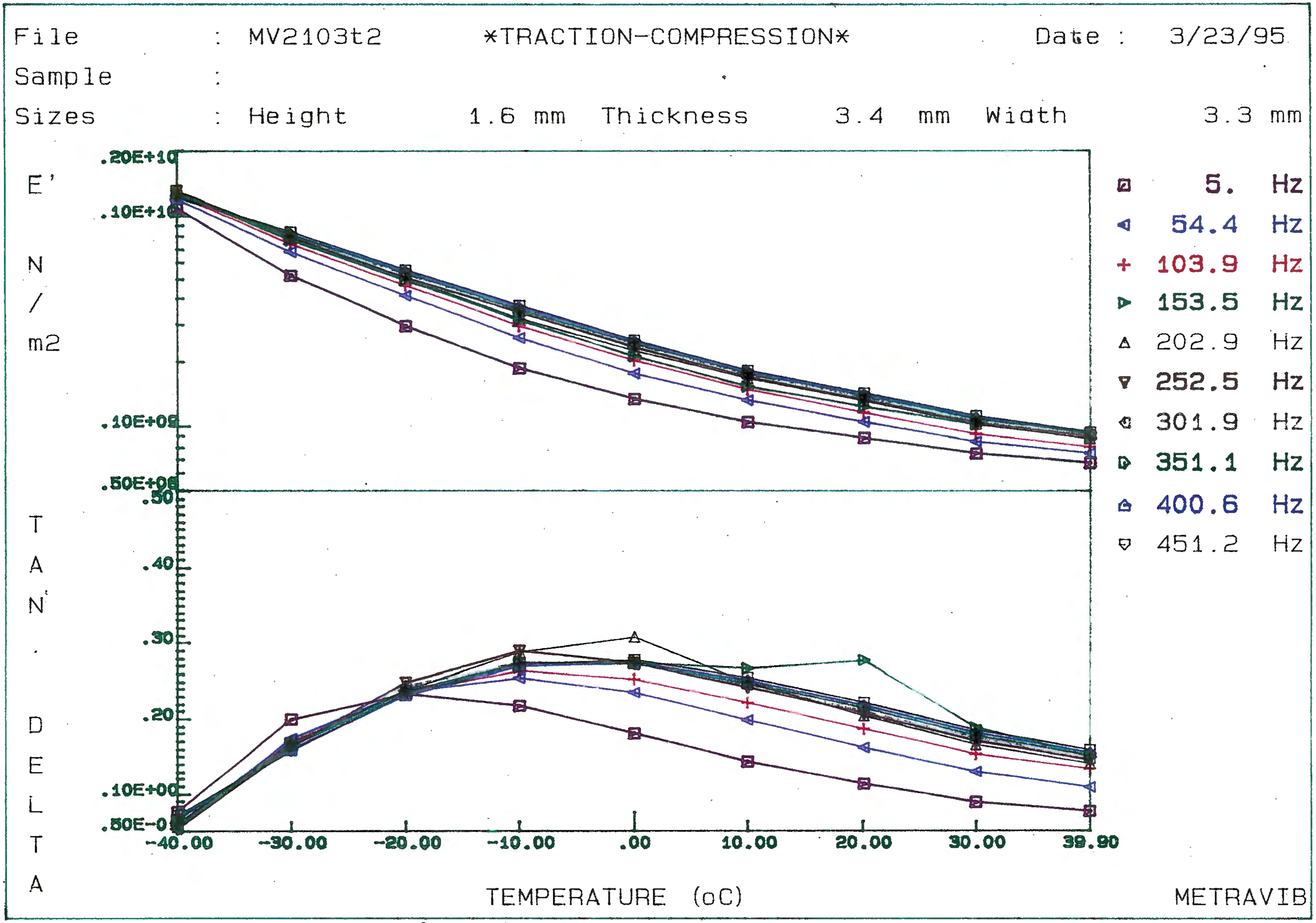


Figure 1. Graph, E' and Tan δ vs. Temperature for 2103-80AE Pellethane

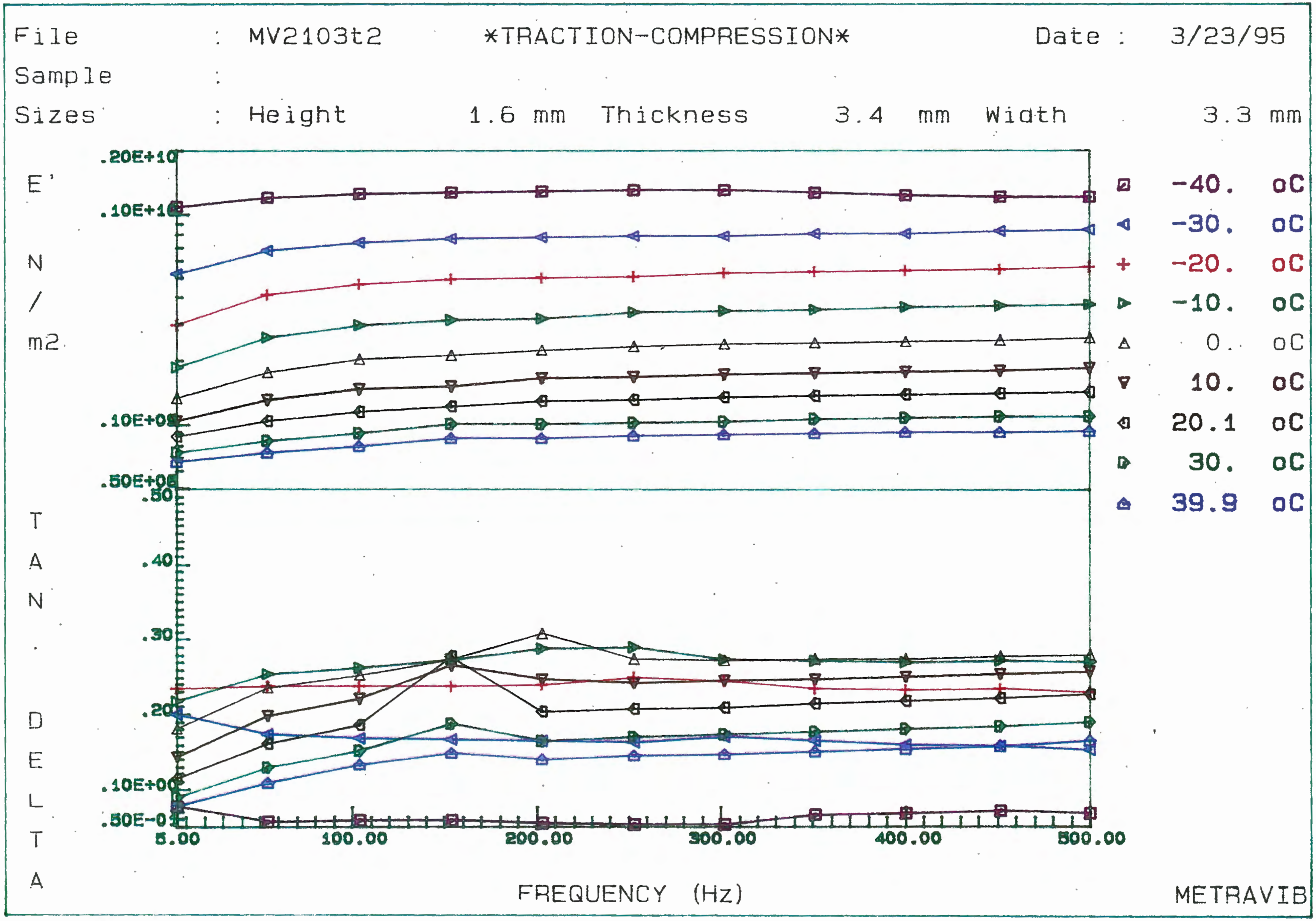


Figure 2. Graph, E' and Tan δ vs. Frequency for 2103-80AE Pellethane

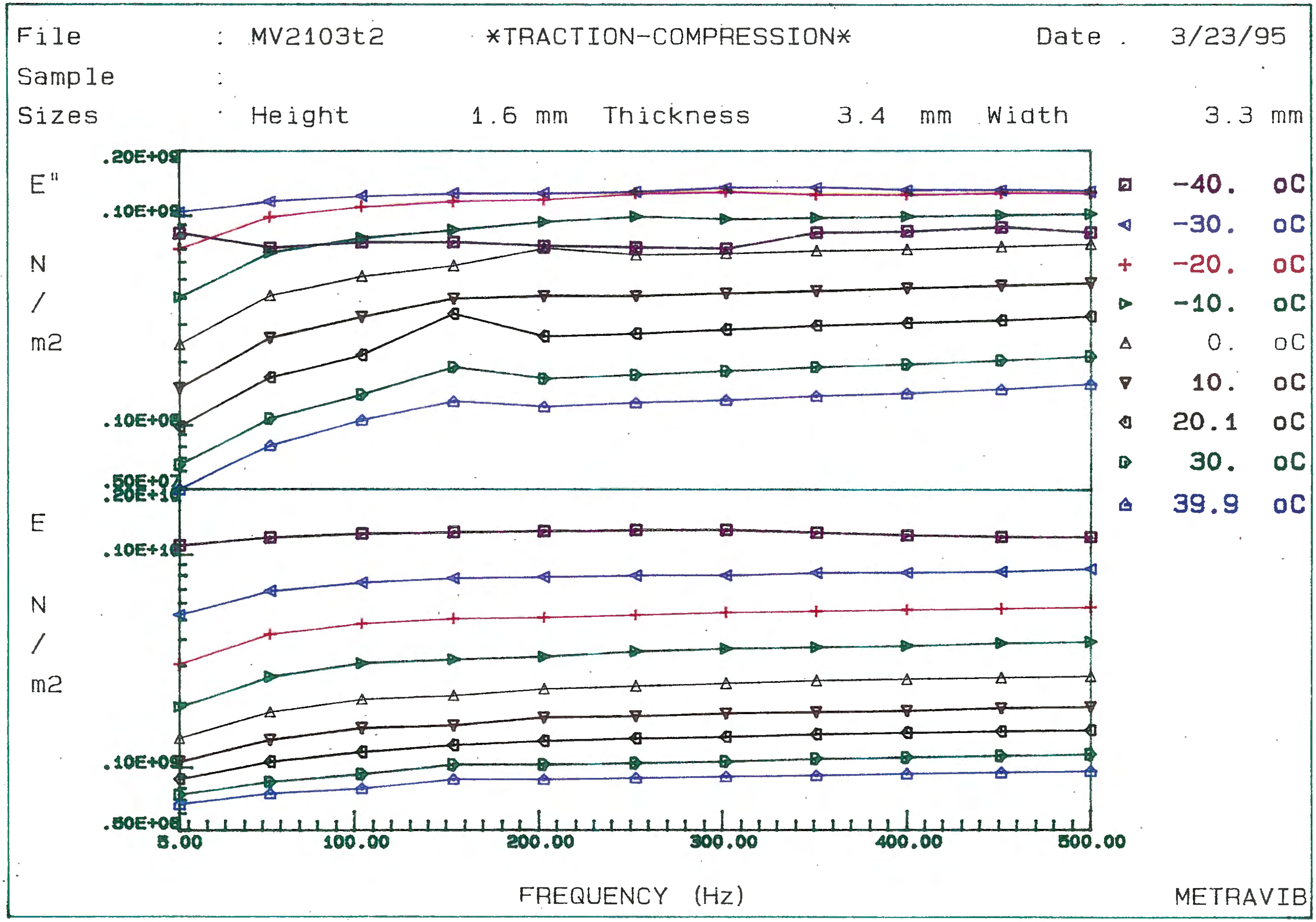


Figure 3. Graph, E" and E* vs. Frequency for 2103-80AE Pellethane

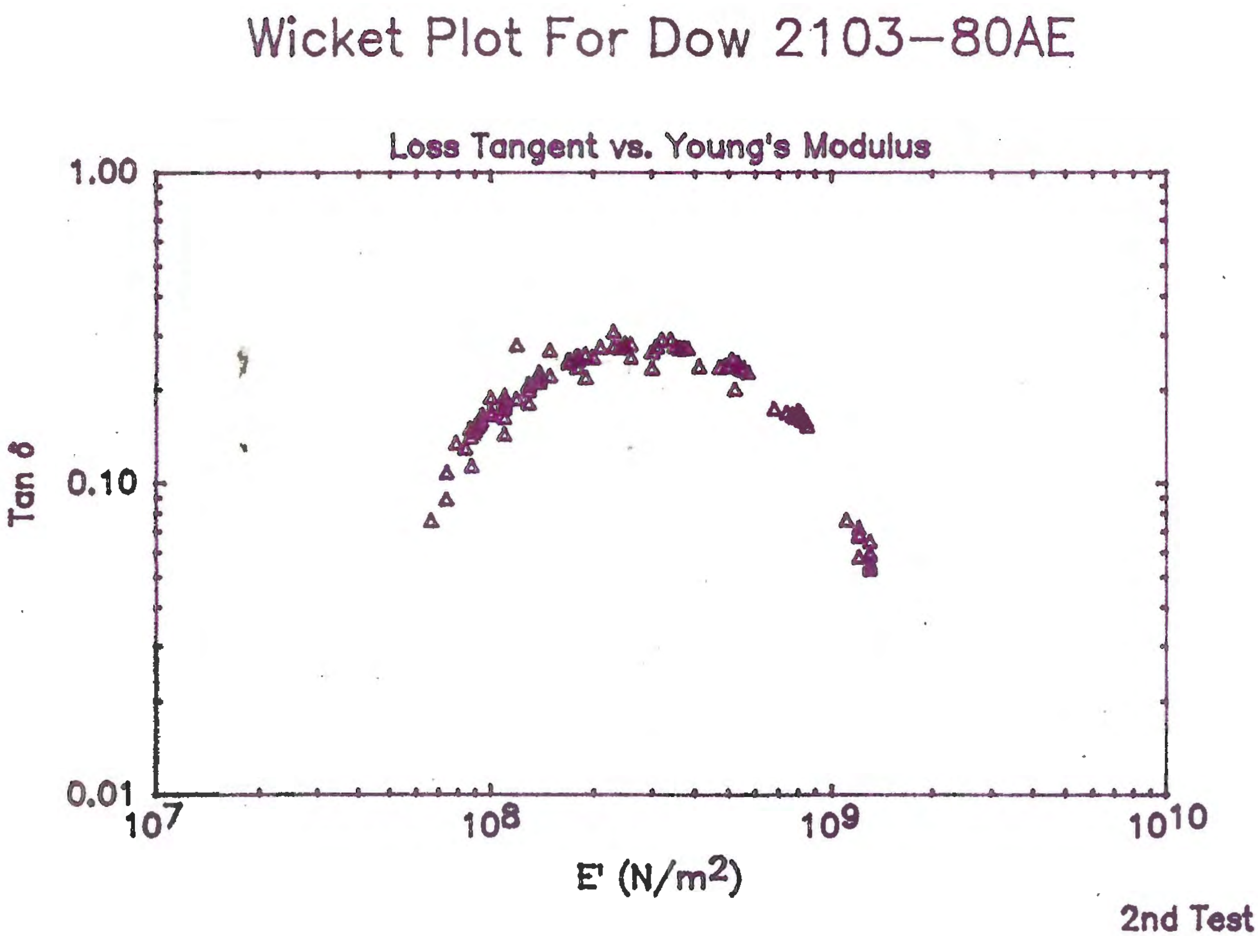


Figure 4. Graph, Wicket Plot for 2103-80AE Pellethane

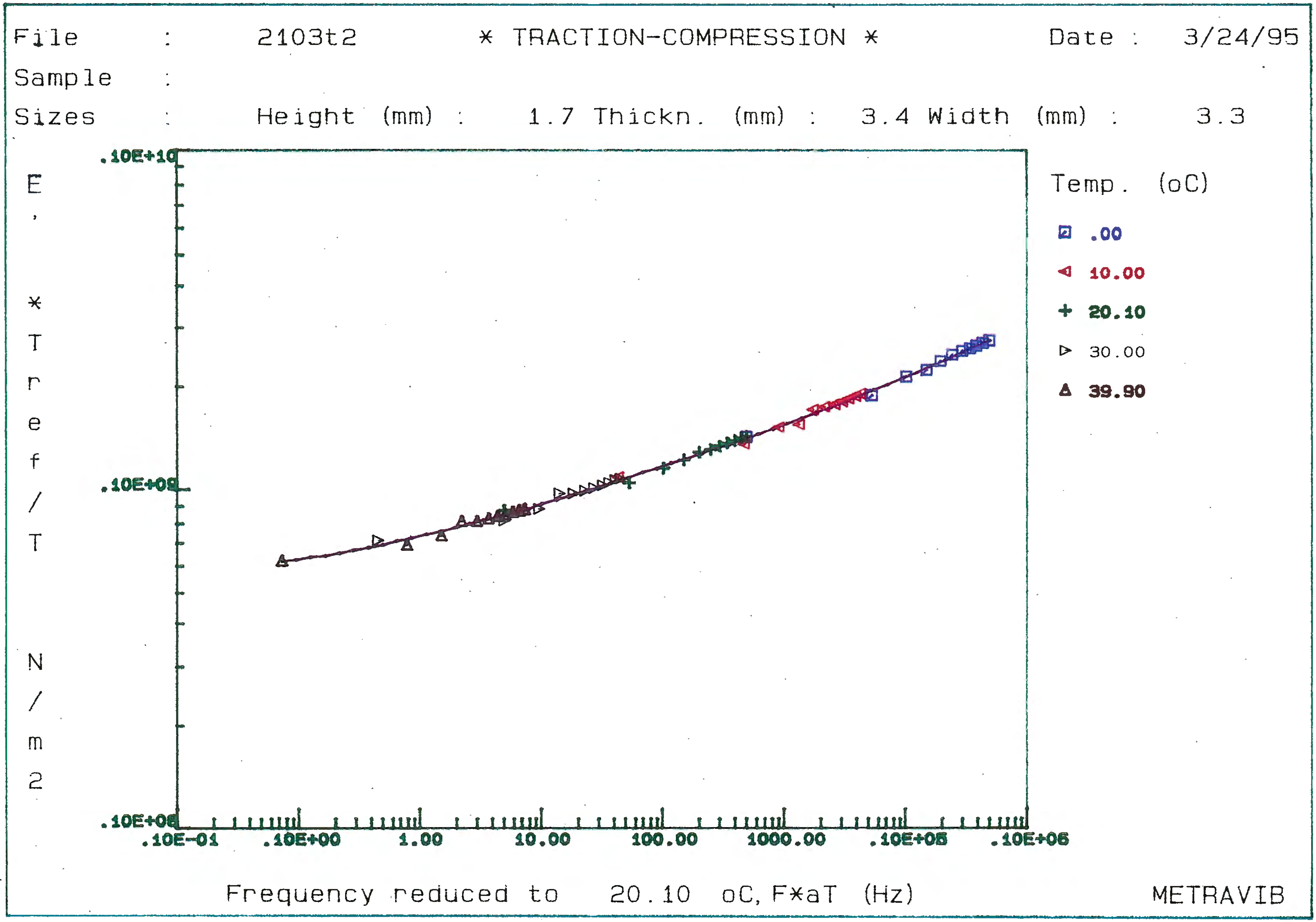


Figure 5. Graph, E' Master Curve for 2103-80AE Pellethane (20°C)

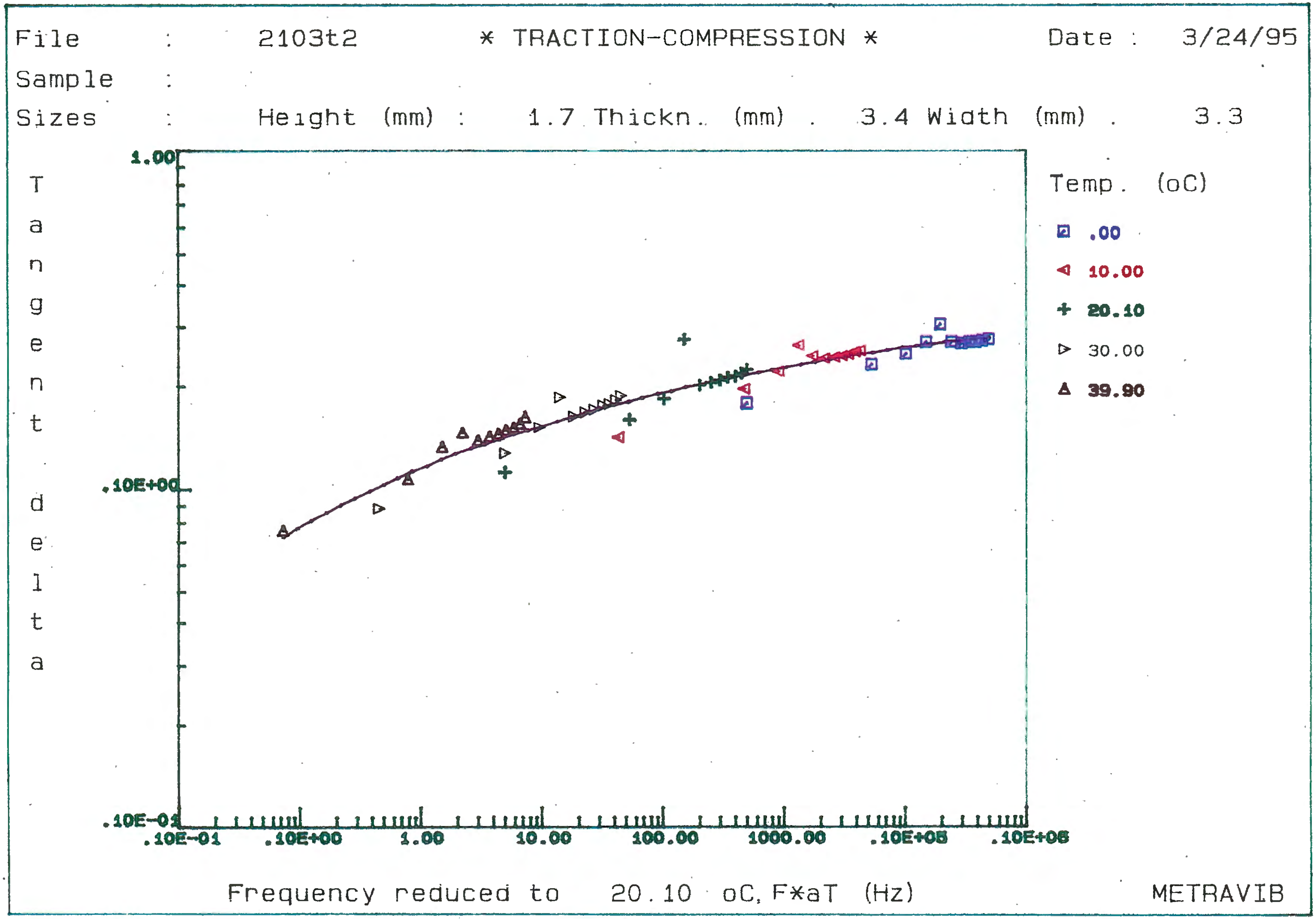


Figure 6. Graph, Tan δ Master Curve for 2103-80AE Pellethane (20°C)

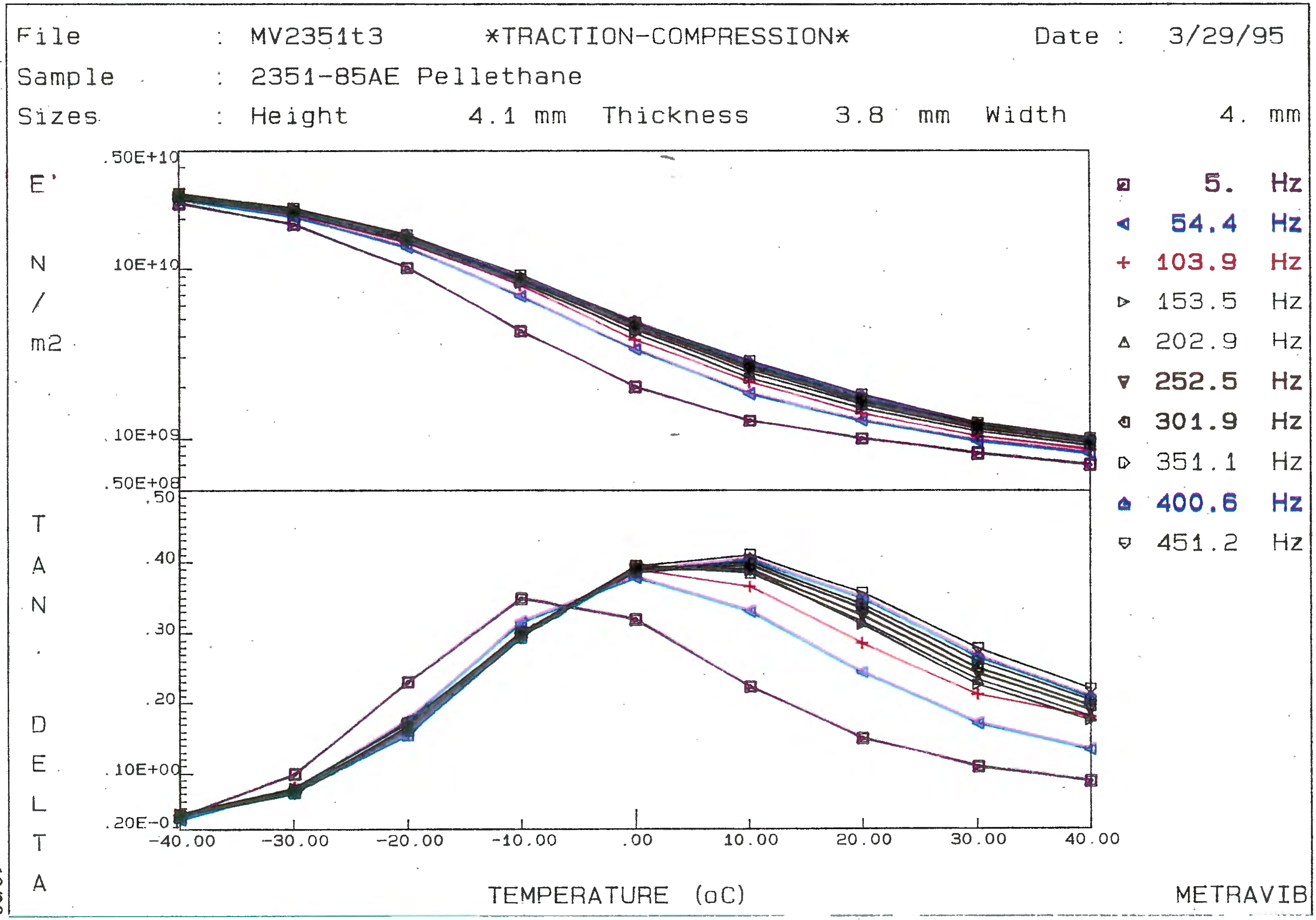


Figure 7. Graph, E' and Tan δ vs. Temperature for 2351-85AE Pellethane

19/20
Reverse Blank

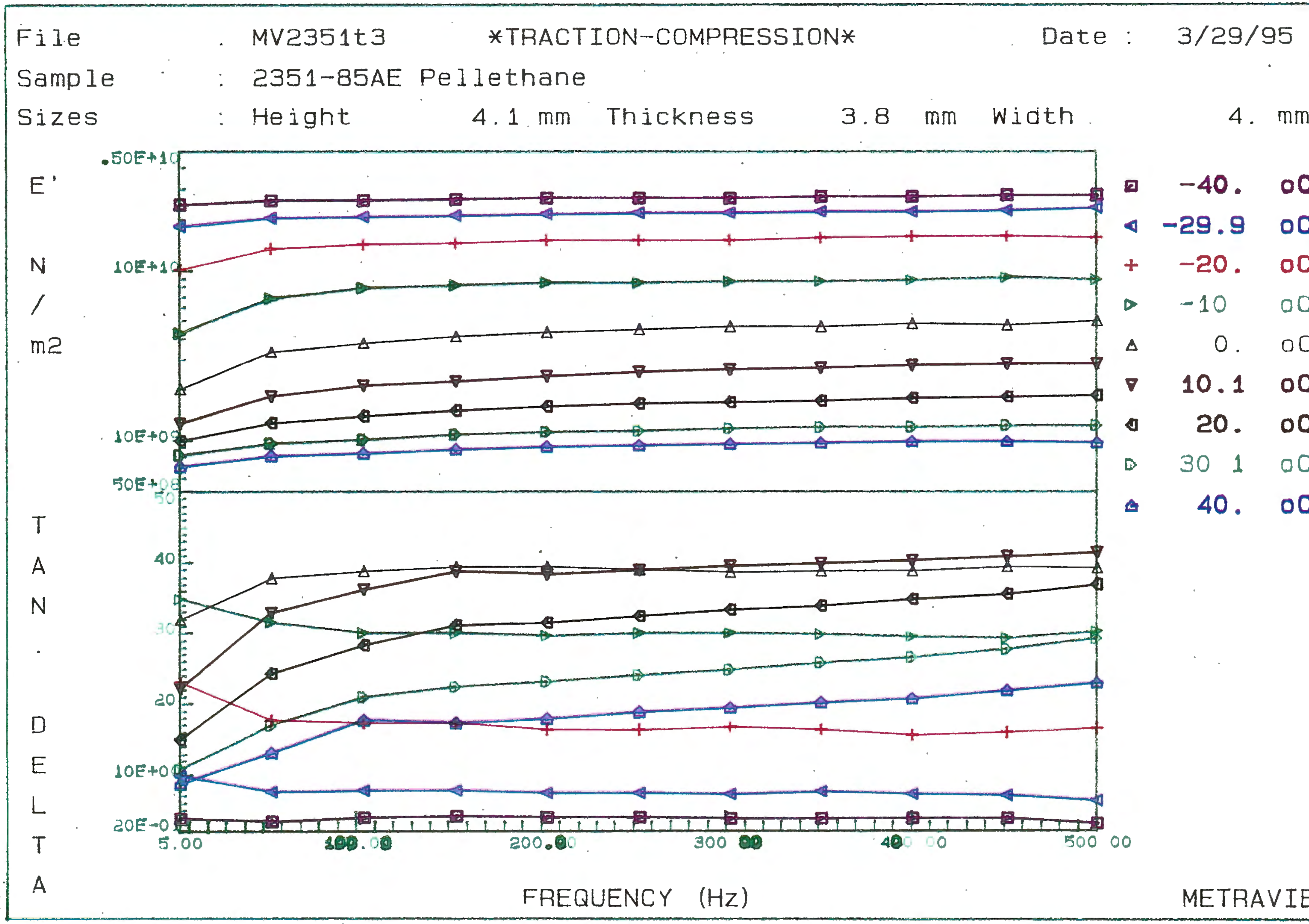


Figure 8. Graph, E' and Tan δ vs. Frequency for 2351-85AE Pellethane

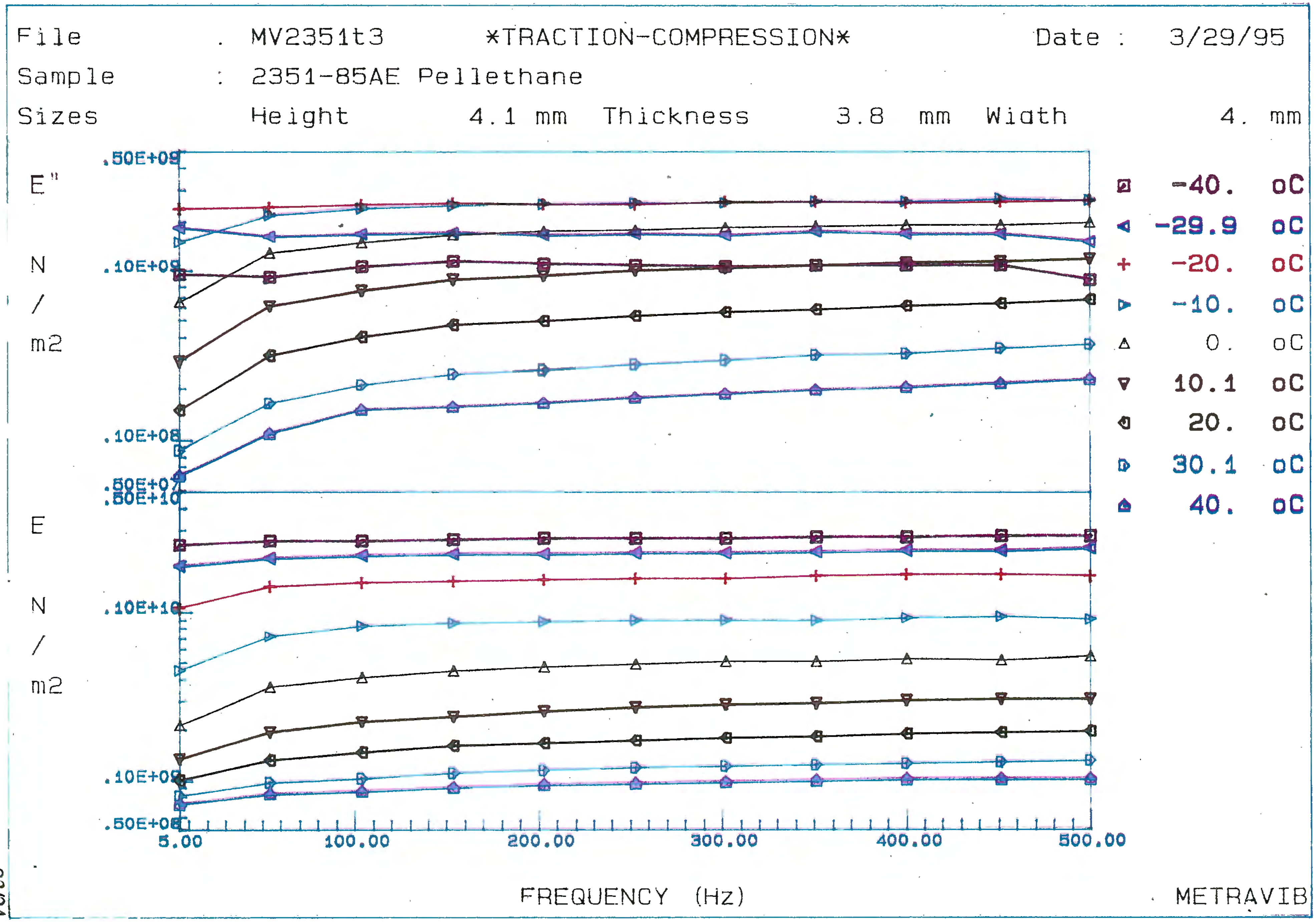


Figure 9. Graph, E" and E* vs. Frequency for 2351-85AE Pellethane

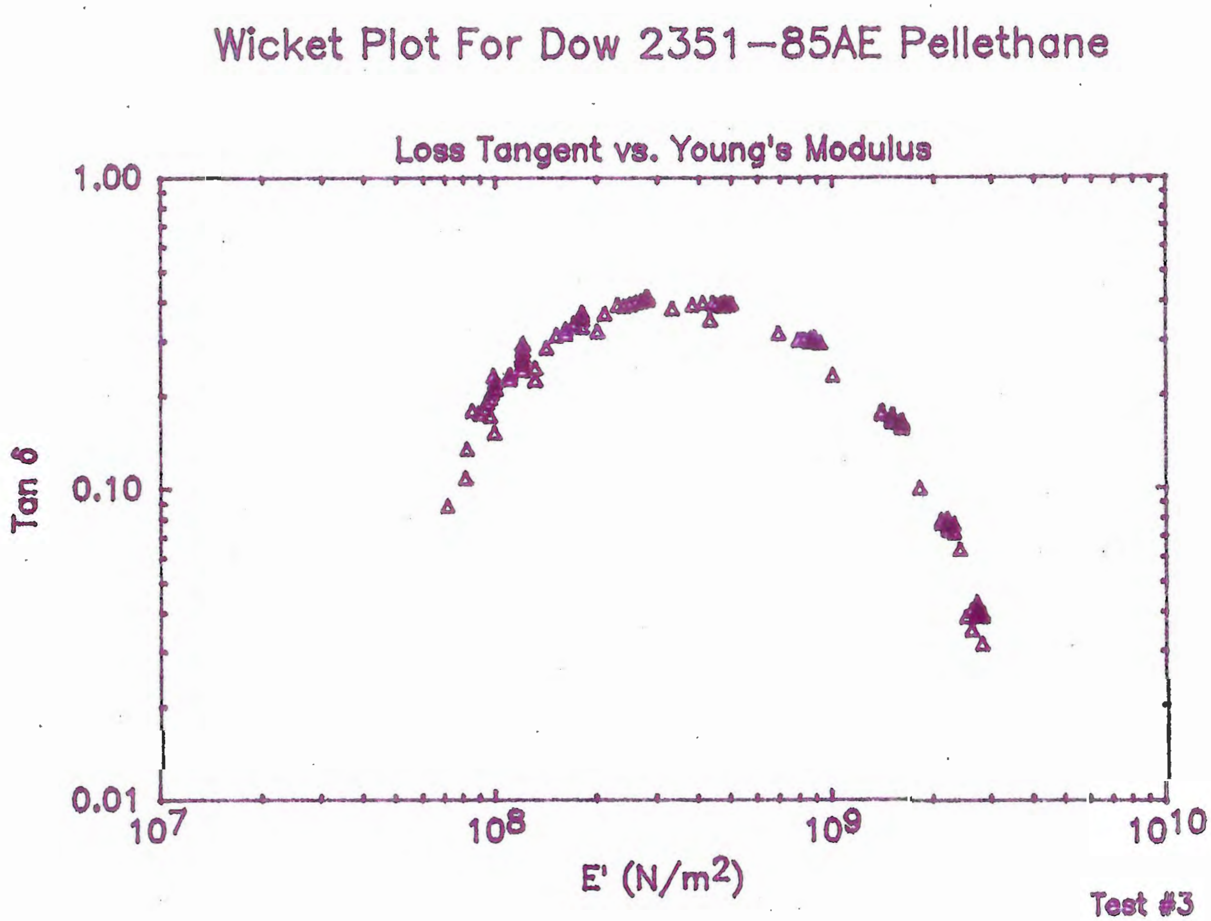


Figure 10. Graph, Wicket Plot for 2351-85AE Pellethane

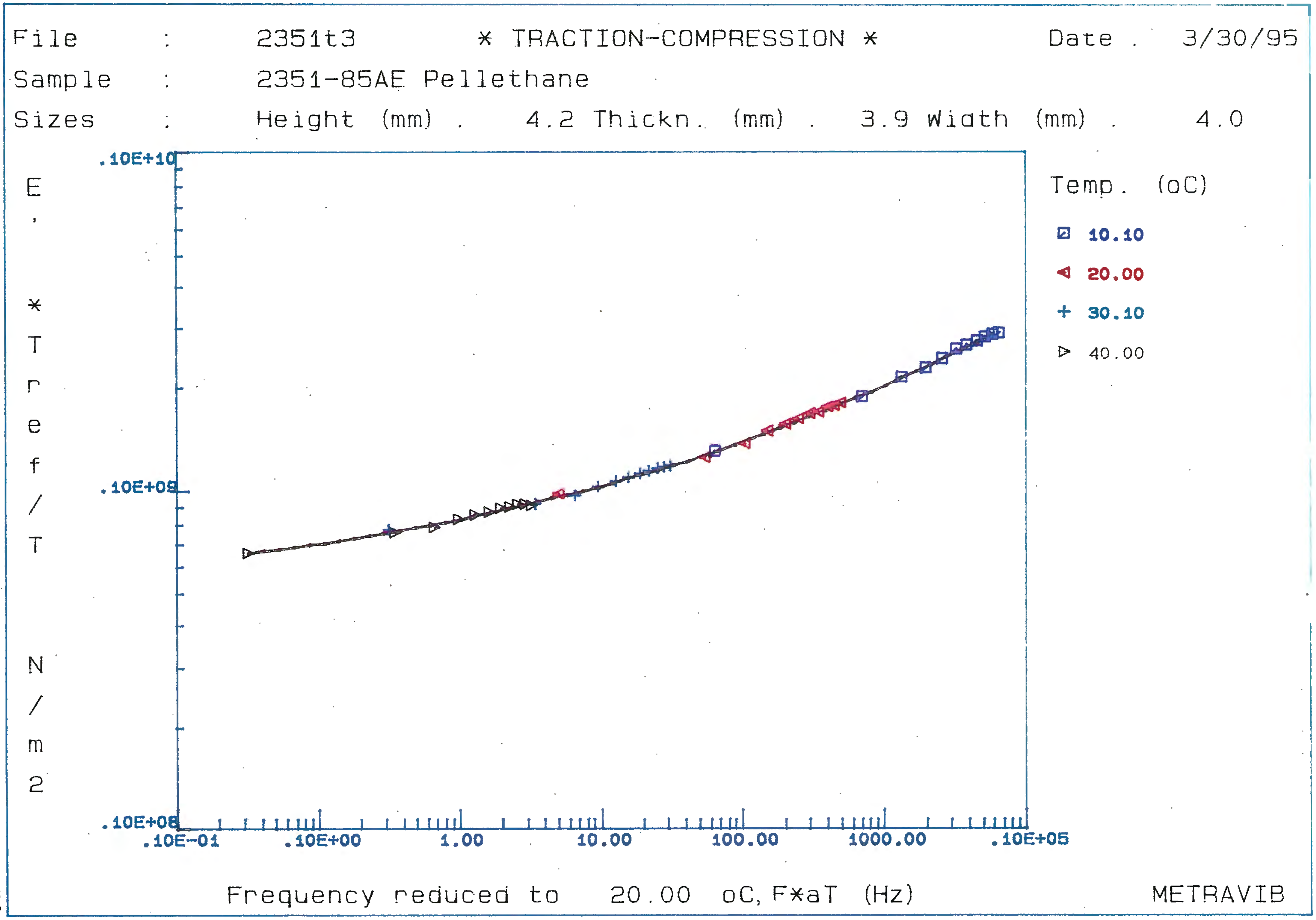


Figure 11. Graph, E' Master Curve for 2351-85AE Pellethane (20°C)

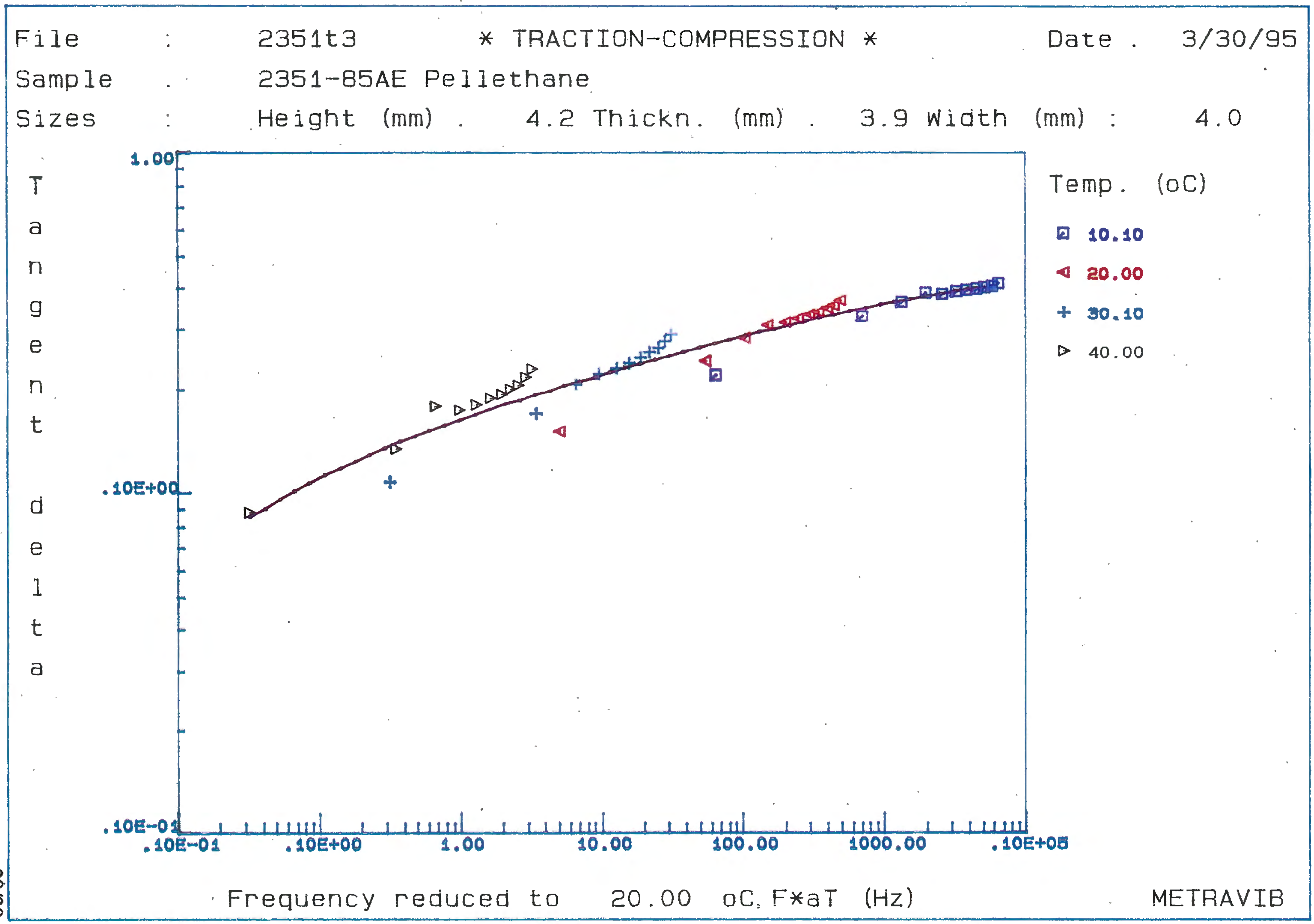


Figure 12. Graph, Tan δ Master Curve for 2351-85AE Pellethane (20°C)

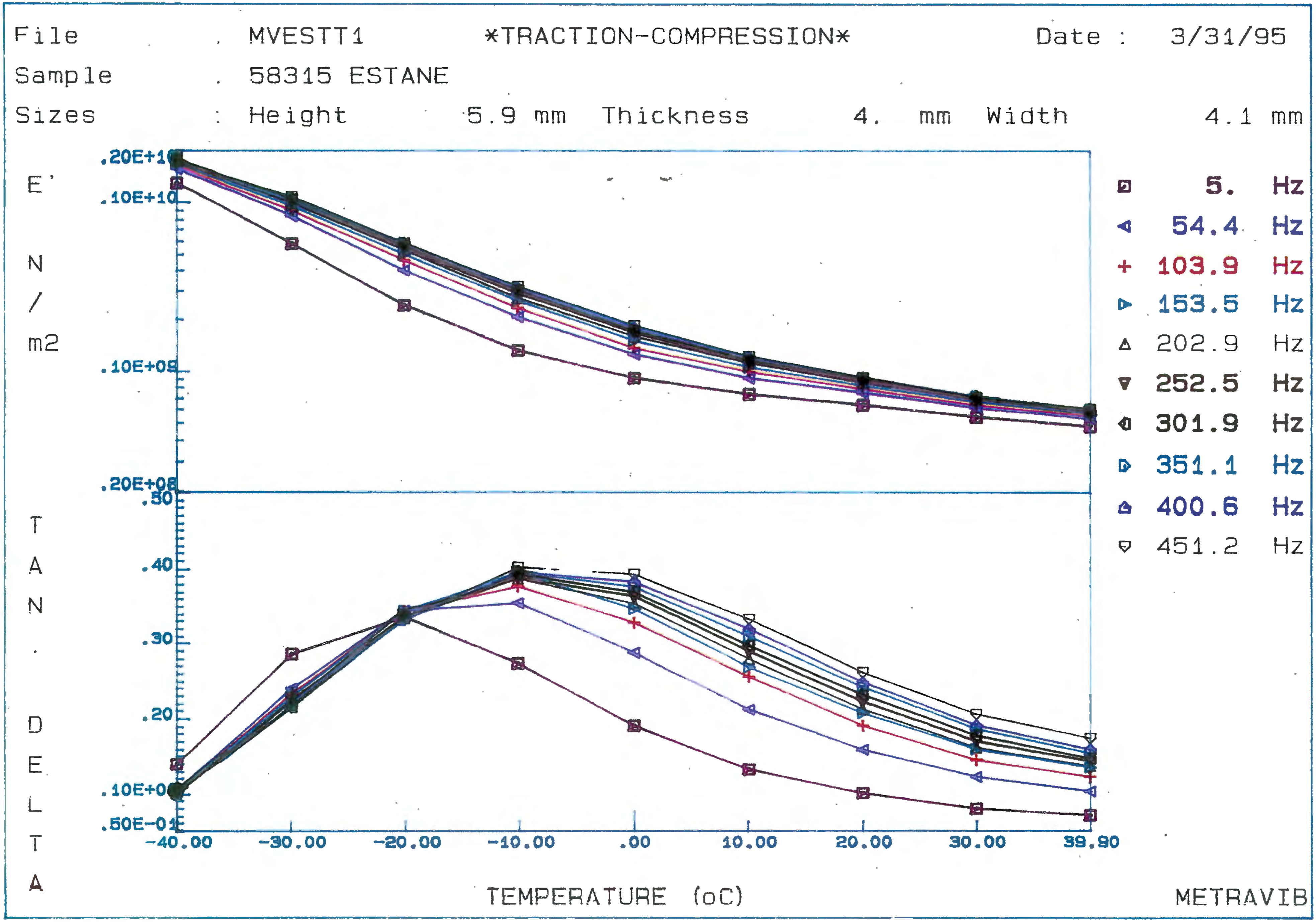


Figure 13. Graph, E' and Tan δ vs. Temperature for 58315 Estane

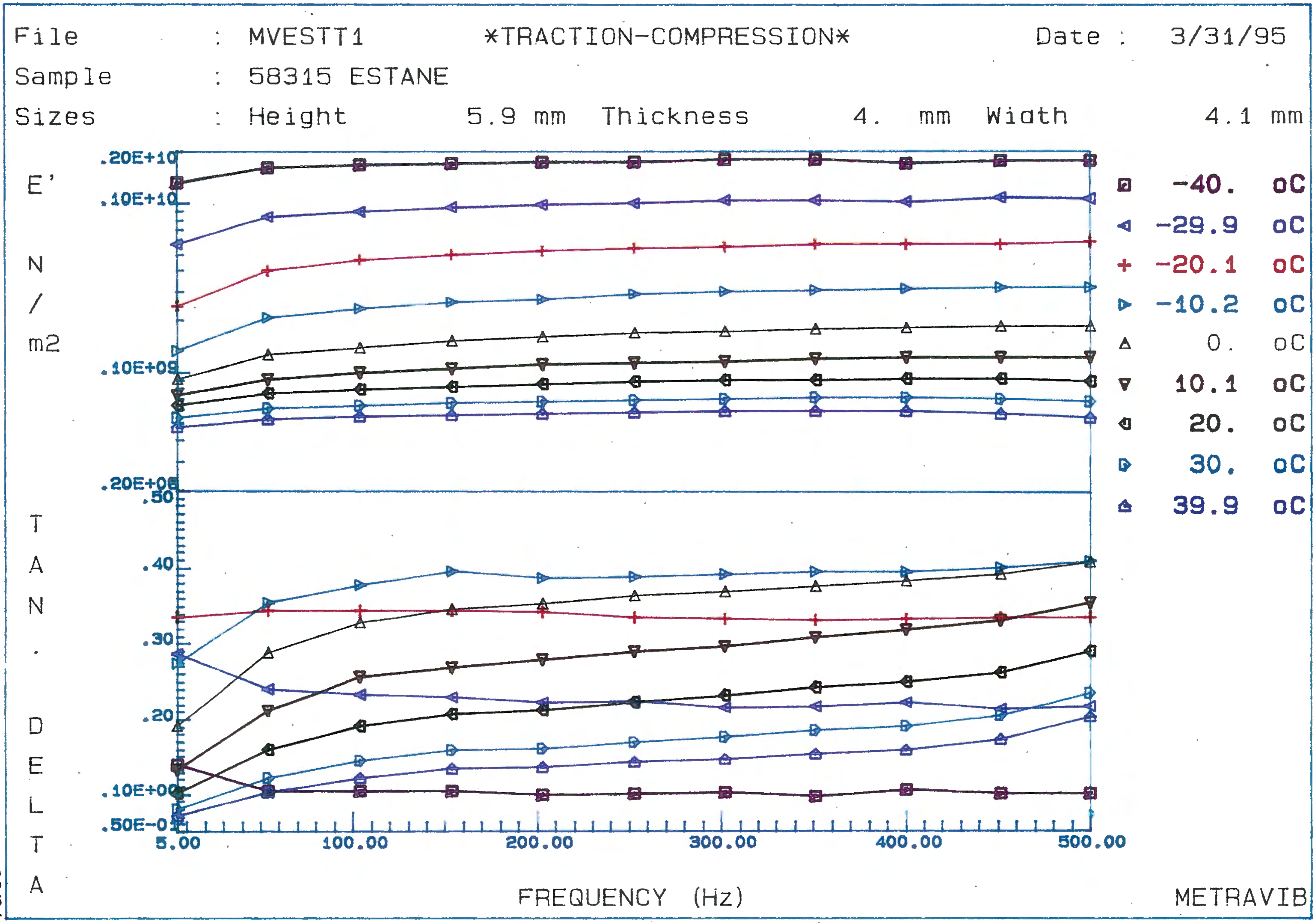


Figure 14. Graph, E' and Tan δ vs. Frequency for 58315 Estane

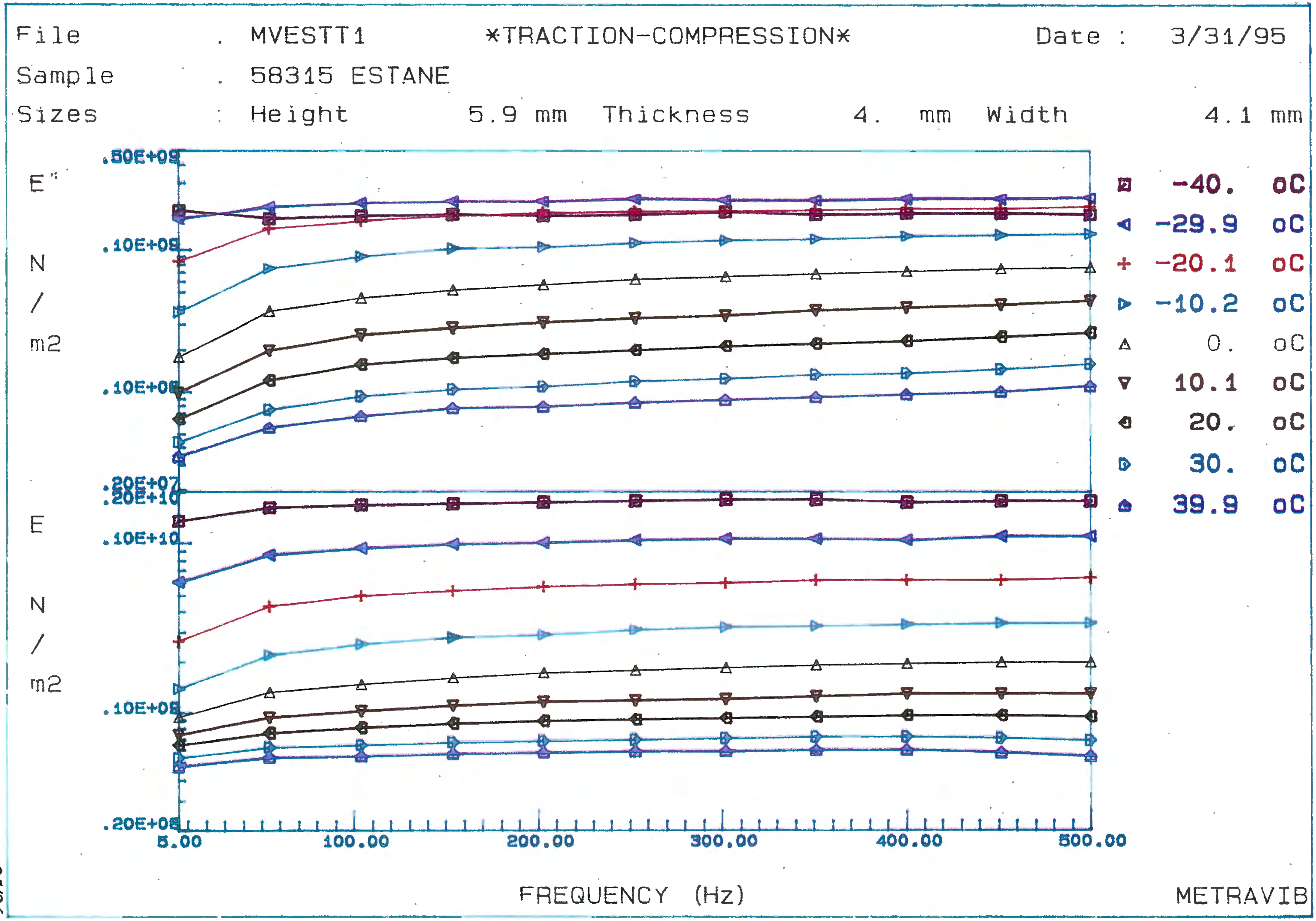


Figure 15. Graph, E" and E* vs. Frequency for 58315 Estane

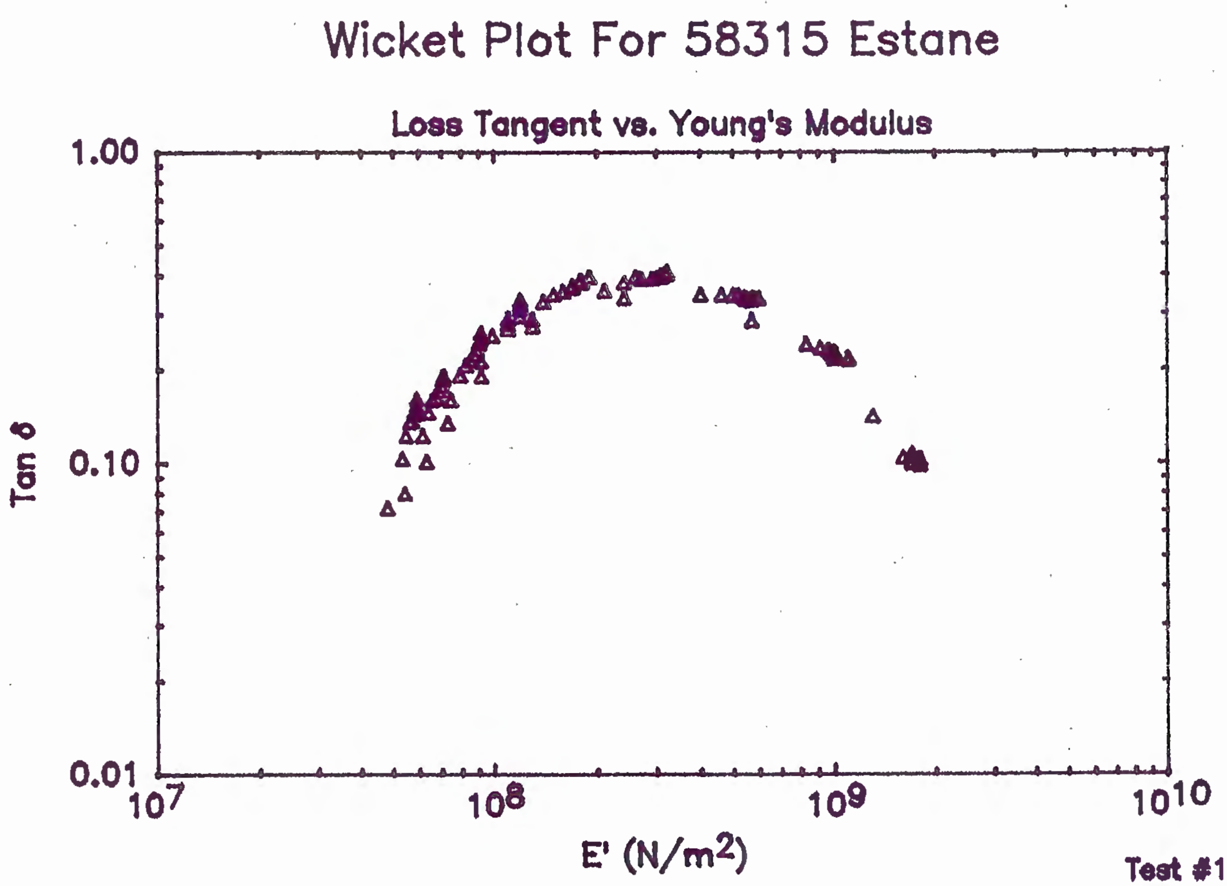


Figure 16. Graph, Wicket Plot for 58315 Estane

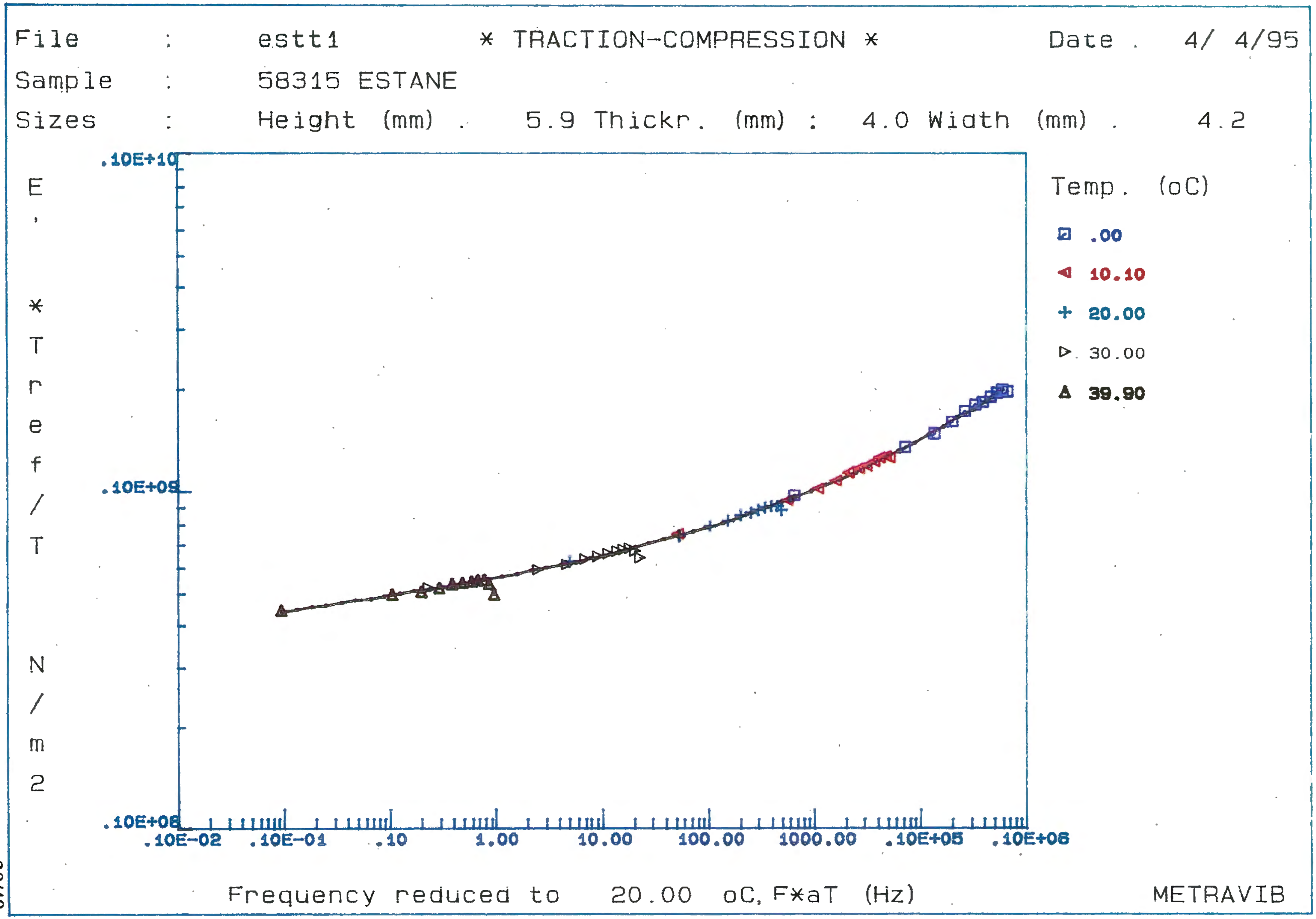


Figure 17. Graph, E' Master Curve for 58315 Estane (20°C)

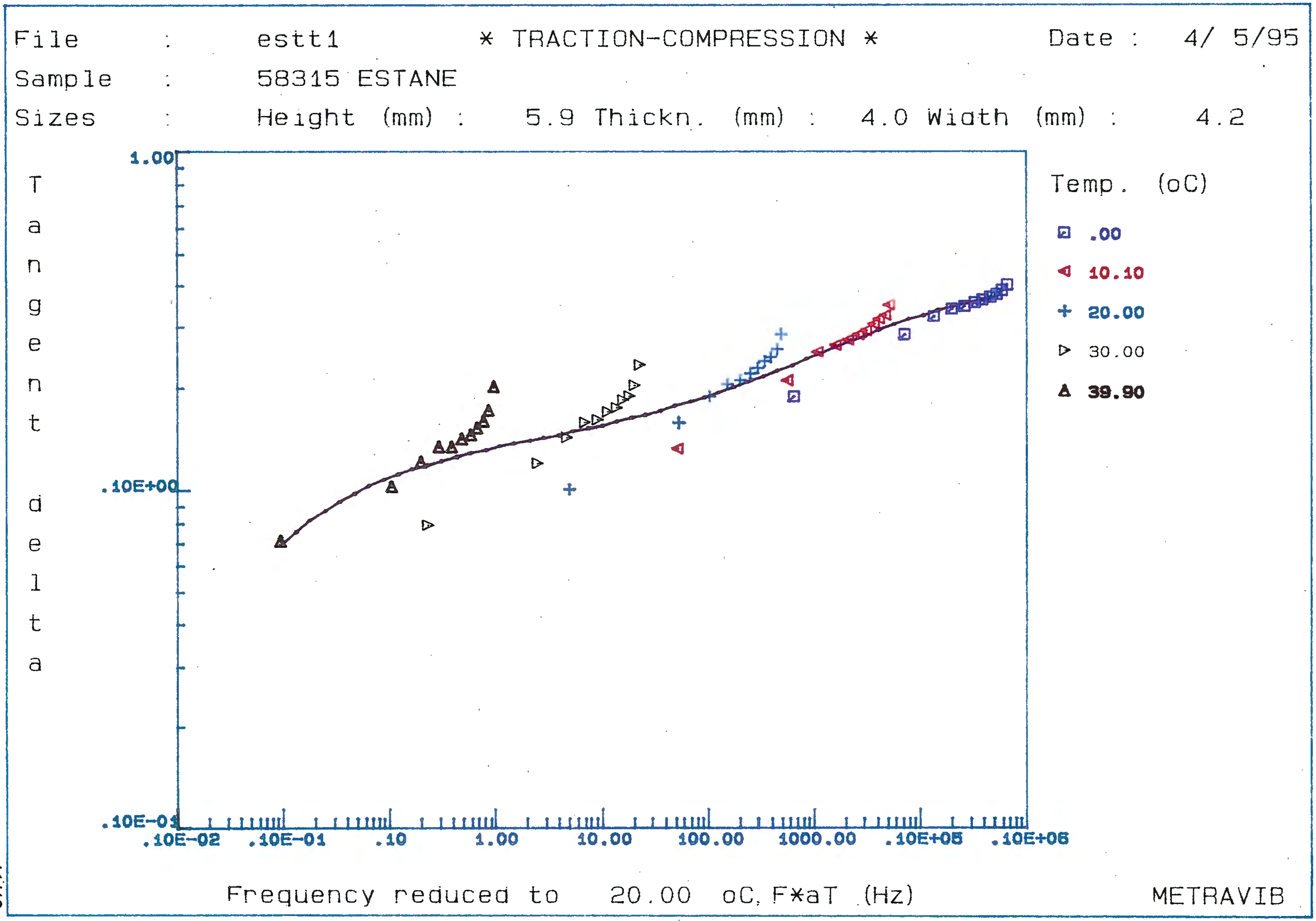


Figure 18. Graph, Tan δ Master Curve for 58315 Estane (20°C)

Table 1. Cut-Off Frequencies for 2103 Pellethane

Temperature (°C)	Tension
-40	500
-30	500
-20	500
-10	500
0	500
10	500
20	500
30	500
40	500

Table 2. Cut-Off Frequencies for 2351-85AE Pellethane

Temperature (°C)	Tension
-40	500
-30	500
-20	500
-10	500
0	500
10	500
20	500
30	500
40	500

Table 3. Cut-Off Frequencies for 58315 Estane

Temperature (°C)	Tension
-40	500
-30	500
-20	500
-10	500
0	500
10	500
20	451.3
30	451.3
40	400.6

Appendix A

Dynamic Tension Tabular Data

for 2103-80AE Pellethane

VISCOANALYSEUR TO :

METRAVIB
instruments

MEASUREMENT FILE......................... MV2103t2

DATE.................................... 3/ 23/ 95

SAMPLE REFERENCE........................

TEST PERFORMED IN : TRACTION COMPRESSION

SAMPLE FEATURES :

- SHAPE................................		PARALLELEPIPEDIC
- HEIGHT...............................	1.68	mm
- THICKNESS............................	3.42	mm
- WIDTH................................	3.33	mm

MEASUREMENT CONDITIONS :

- SCANNING IN TEMPERATURE.............	-40.0 -	39.9	oC
- SCANNING IN FREQUENCY...............	5.0 -	500.0	HERTZ
- REGULATION IN DISPLACEMENT..........		5.0	MICRON
- PRESTRAIN REGULATION................			NO

REMARKS :

TEST PERFORMED BY :

SERVICE :

SAMPLE REFERENCE.........................

TEMPERATURE NUMBER..................... 1

- STARTING TEMPERATURE................. 20.6 oC
- VARIATION RATE OF TEMPERATURE....... 5.0 oC/mn
- STABILIZATION TIME IN TEMPERATURE... 15 mn
- FINAL TEMPERATURE................... -40.0 oC

No	FREQUENCY HERTZ	E' N/m2	E" N/m2	E N/m2	TAN. DELTA
1	5.0	.110E+10	.833E+08	.110E+10	.760E-01
2	54.5	.121E+10	.701E+08	.121E+10	.579E-01
3	104.0	.125E+10	.748E+08	.126E+10	.596E-01
4	153.6	.127E+10	.747E+08	.128E+10	.586E-01
5	202.9	.129E+10	.713E+08	.130E+10	.551E-01
6	252.5	.131E+10	.704E+08	.131E+10	.539E-01
7	301.9	.131E+10	.693E+08	.131E+10	.529E-01
8	351.1	.127E+10	.830E+08	.128E+10	.651E-01
9	400.6	.124E+10	.841E+08	.125E+10	.676E-01
10	451.3	.122E+10	.878E+08	.123E+10	.717E-01
11	500.0	.122E+10	.832E+08	.122E+10	.685E-01

SAMPLE REFERENCE......................

TEMPERATURE NUMBER.................... 2

- STARTING TEMPERATURE................ -40.0 oC
- VARIATION RATE OF TEMPERATURE....... 5.0 oC/mn
- STABILIZATION TIME IN TEMPERATURE... 15 mn
- FINAL TEMPERATURE................... -30.0 oC

No	FREQUENCY HERTZ	E' N/m2	E" N/m2	E N/m2	TAN. DELTA
1	5.0	.519E+09	.104E+09	.530E+09	.200
2	54.5	.679E+09	.117E+09	.689E+09	.173
3	104.0	.742E+09	.125E+09	.752E+09	.168
4	153.6	.766E+09	.127E+09	.776E+09	.166
5	202.9	.779E+09	.128E+09	.789E+09	.164
6	252.5	.790E+09	.129E+09	.800E+09	.163
7	301.9	.796E+09	.135E+09	.808E+09	.170
8	351.1	.816E+09	.135E+09	.827E+09	.165
9	400.6	.821E+09	.131E+09	.831E+09	.159
10	451.3	.835E+09	.132E+09	.845E+09	.158
11	500.0	.849E+09	.129E+09	.858E+09	.152

SAMPLE REFERENCE........................

TEMPERATURE NUMBER.................... 3

- STARTING TEMPERATURE................ -30.0 oC
- VARIATION RATE OF TEMPERATURE....... 5.0 oC/mn
- STABILIZATION TIME IN TEMPERATURE... 15 mn
- FINAL TEMPERATURE................... -20.0 oC

No	FREQUENCY HERTZ	E' N/m2	E" N/m2	E N/m2	TAN. DELTA
1	5.0	.298E+09	.698E+08	.306E+09	.234
2	54.5	.414E+09	.981E+08	.425E+09	.237
3	104.0	.466E+09	.110E+09	.479E+09	.236
4	153.6	.489E+09	.116E+09	.503E+09	.238
5	202.9	.502E+09	.119E+09	.516E+09	.238
6	252.5	.509E+09	.127E+09	.525E+09	.250
7	301.9	.528E+09	.129E+09	.543E+09	.244
8	351.1	.539E+09	.126E+09	.554E+09	.234
9	400.6	.546E+09	.127E+09	.560E+09	.232
10	451.3	.550E+09	.128E+09	.565E+09	.233
11	500.0	.565E+09	.128E+09	.579E+09	.227

SAMPLE REFERENCE........................

TEMPERATURE NUMBER.................... 4

- STARTING TEMPERATURE................ -20.0 oC
- VARIATION RATE OF TEMPERATURE....... 5.0 oC/mn
- STABILIZATION TIME IN TEMPERATURE... 15 mn
- FINAL TEMPERATURE................... -10.0 oC

No	FREQUENCY HERTZ	E' N/m2	E" N/m2	E N/m2	TAN. DELTA
1	5.0	.188E+09	.408E+08	.192E+09	.218
2	54.5	.260E+09	.662E+08	.269E+09	.254
3	104.0	.298E+09	.785E+08	.308E+09	.264
4	153.6	.312E+09	.854E+08	.324E+09	.274
5	202.9	.321E+09	.927E+08	.334E+09	.289
6	252.5	.340E+09	.984E+08	.354E+09	.289
7	301.9	.348E+09	.957E+08	.361E+09	.275
8	351.1	.355E+09	.967E+08	.368E+09	.272
9	400.6	.363E+09	.984E+08	.376E+09	.271
10	451.3	.369E+09	.100E+09	.382E+09	.272
11	500.0	.376E+09	.102E+09	.389E+09	.271

SAMPLE REFERENCE.......................

TEMPERATURE NUMBER.................... 5

- STARTING TEMPERATURE................ -10.0 oC
- VARIATION RATE OF TEMPERATURE....... 5.0 oC/mn
- STABILIZATION TIME IN TEMPERATURE... 15 mn
- FINAL TEMPERATURE................... .0 oC

No	FREQUENCY HERTZ	E' N/m2	E" N/m2	E N/m2	TAN. DELTA
1	5.0	.134E+09	.242E+08	.136E+09	.180
2	54.5	.177E+09	.416E+08	.182E+09	.235
3	104.0	.202E+09	.512E+08	.209E+09	.253
4	153.6	.211E+09	.578E+08	.219E+09	.273
5	202.9	.226E+09	.694E+08	.236E+09	.307
6	252.5	.234E+09	.643E+08	.243E+09	.274
7	301.9	.240E+09	.655E+08	.249E+09	.272
8	351.1	.246E+09	.673E+08	.255E+09	.274
9	400.6	.250E+09	.686E+08	.259E+09	.275
10	451.3	.254E+09	.705E+08	.264E+09	.277
11	500.0	.259E+09	.723E+08	.269E+09	.279

SAMPLE REFERENCE........................

TEMPERATURE NUMBER.................... 6

- STARTING TEMPERATURE................ .0 oC
- VARIATION RATE OF TEMPERATURE....... 5.0 oC/mn
- STABILIZATION TIME IN TEMPERATURE... 15 mn
- FINAL TEMPERATURE................... 10.0 oC

No	FREQUENCY HERTZ	E' N/m2	E" N/m2	E N/m2	TAN. DELTA
1	5.0	.105E+09	.151E+08	.106E+09	.143
2	54.5	.131E+09	.260E+08	.134E+09	.198
3	104.0	.148E+09	.328E+08	.152E+09	.221
4	153.6	.151E+09	.403E+08	.157E+09	.267
5	202.9	.167E+09	.413E+08	.172E+09	.248
6	252.5	.170E+09	.412E+08	.175E+09	.243
7	301.9	.173E+09	.425E+08	.178E+09	.245
8	351.1	.176E+09	.438E+08	.182E+09	.248
9	400.6	.179E+09	.449E+08	.185E+09	.251
10	451.3	.182E+09	.464E+08	.188E+09	.254
11	500.0	.185E+09	.478E+08	.192E+09	.258

SAMPLE REFERENCE.........................

TEMPERATURE NUMBER.....................   7

- STARTING TEMPERATURE.................   10.0 oC
- VARIATION RATE OF TEMPERATURE........   5.0 oC/mn
- STABILIZATION TIME IN TEMPERATURE...   15 mn
- FINAL TEMPERATURE...................   20.1 oC

No	FREQUENCY HERTZ	E' N/m2	E" N/m2	E N/m2	TAN. DELTA
1	5.0	.878E+08	.991E+07	.883E+08	.113
2	54.5	.105E+09	.169E+08	.106E+09	.162
3	104.0	.116E+09	.216E+08	.118E+09	.186
4	153.6	.122E+09	.339E+08	.127E+09	.278
5	202.9	.130E+09	.264E+08	.132E+09	.204
6	252.5	.132E+09	.273E+08	.135E+09	.206
7	301.9	.135E+09	.283E+08	.138E+09	.210
8	351.1	.138E+09	.295E+08	.141E+09	.214
9	400.6	.140E+09	.304E+08	.143E+09	.217
10	451.3	.142E+09	.314E+08	.146E+09	.221
11	500.0	.144E+09	.326E+08	.148E+09	.226

SAMPLE REFERENCE.......................

TEMPERATURE NUMBER.................... 8

- STARTING TEMPERATURE................ 20.1 oC
- VARIATION RATE OF TEMPERATURE....... 5.0 oC/mn
- STABILIZATION TIME IN TEMPERATURE... 15 mn
- FINAL TEMPERATURE................... 30.0 oC

No	FREQUENCY HERTZ	E' N/m2	E" N/m2	E N/m2	TAN. DELTA
1	5.0	.736E+08	.653E+07	.739E+08	.886E-01
2	54.5	.841E+08	.108E+08	.848E+08	.129
3	104.0	.915E+08	.140E+08	.926E+08	.153
4	153.6	.101E+09	.190E+08	.103E+09	.188
5	202.9	.101E+09	.167E+08	.103E+09	.165
6	252.5	.103E+09	.175E+08	.105E+09	.169
7	301.9	.105E+09	.182E+08	.107E+09	.173
8	351.1	.107E+09	.189E+08	.109E+09	.177
9	400.6	.109E+09	.195E+08	.110E+09	.180
10	451.3	.110E+09	.202E+08	.112E+09	.183
11	500.0	.111E+09	.211E+08	.113E+09	.190

SAMPLE REFERENCE.........................

TEMPERATURE NUMBER.................... 9

- STARTING TEMPERATURE................ 30.0 oC
- VARIATION RATE OF TEMPERATURE....... 5.0 oC/mn
- STABILIZATION TIME IN TEMPERATURE... 15 mn
- FINAL TEMPERATURE................... 39.9 oC

No	FREQUENCY HERTZ	E′ N/m2	E" N/m2	E N/m2	TAN. DELTA
1	5.0	.664E+08	.502E+07	.666E+08	.756E-01
2	54.5	.740E+08	.803E+07	.745E+08	.108
3	104.0	.790E+08	.106E+08	.797E+08	.134
4	153.6	.870E+08	.129E+08	.879E+08	.149
5	202.9	.872E+08	.122E+08	.881E+08	.140
6	252.5	.886E+08	.128E+08	.895E+08	.145
7	301.9	.899E+08	.133E+08	.909E+08	.147
8	351.1	.913E+08	.138E+08	.923E+08	.151
9	400.6	.926E+08	.143E+08	.937E+08	.154
10	451.3	.936E+08	.148E+08	.948E+08	.158
11	500.0	.944E+08	.156E+08	.957E+08	.165

Appendix B

DSC Measurement

DEPARTMENT OF THE NAVY
NAVAL UNDERSEA WARFARE CENTER DIVISION
1176 HOWELL STREET
NEWPORT RI 02841-1708

NAVAL UNDERSEA WARFARE CENTER DETACHMENT, NEW LONDON
39 SMITH STREET
NEW LONDON CT 06320-5594

IN REPLY REFER TO:
Ser 52131/45
04 APR 95

MEMORANDUM

From: Code 2131 (T. Ramotowski)
To: Code 4221 (R. LaFreniere)

Sbj: DSC-DETERMINED GLASS TRANSITION TEMPERATURES FOR DOW PELLETHANE AND B. F. GOODRICH ESTANE SAMPLES

Ref: (a) Capps, Roger N., 1989, *Elastomeric Materials for Acoustical Applications*, Naval Research Laboratory, Underwater Sound Reference Detachment, Orlando, FL, 335 pp.

1) Recently, samples of three different elastomeric materials, Dow Pellethane 2103-80AE, Dow Pellethane 2351-85AE and B. F. Goodrich Estane 58315, were dropped off at the NUWCDETNLON Code 2131 Chemistry Laboratory. The Chemistry Laboratory was asked to determine the glass transition temperature, T_g, of each of the three materials. The purpose of this memorandum is to provide the requested information and to document the procedure used to obtain that information. The following table provides a summary of the results obtained during this investigation:

Sample	T_g Via Computer Calculation	T_g Via Heat Flow Derivative Local Maxima
Dow Pellethane 2103-80AE	-45.8°C	-47.6°C
Dow Pellethane 2351-85AE	-25.4°C	-29.3°C
BF Goodrich Estane 58315	-45.7°C	-47.6°C

2) The NUWCDETNLON Code 2131 Chemistry Laboratory's differential scanning calorimeter (DSC) was used to determine the T_gs of the three materials. The DSC measures changes in heat flow within a sample as the sample is heated at a controlled rate. When a material passes through its glass transition region, it exhibits a change in its heat capacity. Typical DSC thermograms, which use temperature as the "X" axis and heat flow as the "Y" axis, display a glass transition as a "step" in the heat flow trace. The Chemistry Laboratory's DuPont model 910 DSC cell connected to a TA Instruments' model 2100 thermal analyzer/computer was used to

obtain the T_g data reported in the above table. The standard DSC analysis software program was used to determine the T_gs of the three samples.

3) Because all three samples obviously had a T_gs below room temperature (i.e., they were all "rubbery" at room temperature), the DSC cell and samples were cooled to a temperature of at least -125°C prior to the start of the data collection runs. The DSC data collection program used was the following:

1) Data collection rate = 0.6 seconds/point;
2) Set purge gas to nitrogen;
3) Ramp 15°C per minute to 400°C.

4) Figures (1) through (3) are copies of the DSC thermograms obtained during this investigation from the three different sample materials. All of the thermograms show a "step-like" shift in their DSC heat flow traces typical of the change observed in heat capacity as a material is heated through its glass transition. The thermal analysis computer software determines glass transition temperatures by calculating tangents to the portions of the heat flow trace immediately before and after the T_g "step." This method for calculating T_gs is designated "T_g Via Computer Calculation" in the table which immediately follows paragraph (1). The glass transition "step" also contains an inflection point at which the slope of the first derivative of the heat flow trace with respect to temperature changes sign from positive to negative. Some polymer experts use the "X" coordinate of this inflection point as a material's glass transition temperature; this method for calculating T_gs is designated "T_g Via Heat Flow Derivative Local Maxima" in the table which immediately follows paragraph (1). All three materials' glass transitions are somewhat broad and gradual, a property which has been associated with "damping character" when encountered with other elastomeric samples in the past. This suggests that all three materials probably exhibit damping characteristics to some extent, with the two Dow Pellethane elastomers being somewhat more damped than the B. F. Goodrich Estane elastomer.

5) T_gs obtained by a calorimetric method (such as DSC) tend to be somewhat lower than the T_gs obtained by dynamic mechanical equipment at low frequencies (such as the Metrovib). Reference (a) suggests that the difference may be as much as 15°C. This effect may be somewhat enhanced by the use of the rather rapid 15°C per minute DSC heating rate. Past experience has indicated that, although such rates enhance the deductibility of a material's T_g, they also occasionally cause some samples to experience "thermal lag" (i.e., the sample is actually at a lower temperature than indicated by the DSC thermogram due to the insulative effects of the outer surfaces of the sample on its interior). The effect of this particular source of error/temperature difference is considered to be minor, however, due to the small size of the samples used.

6) Questions concerning this memorandum should be directed to the undersigned at x4292 (NL).

THOMAS RAMOTOWSKI
Chemist

Copy to: 2131
2131 (Ramotowski)
2131s
MMC (R. Tyron)

Figure 1: DSC thermogram from -100°C to +100°C for Dow Pellethane 2103-80AE elastomer. Curve (A) is the DSC heat flow trace; curve (B) is the first derivative of the DSC heat flow trace with respect to temperature. The computer software calculated T_g is indicated by a Roman numeral "I" in parentheses.

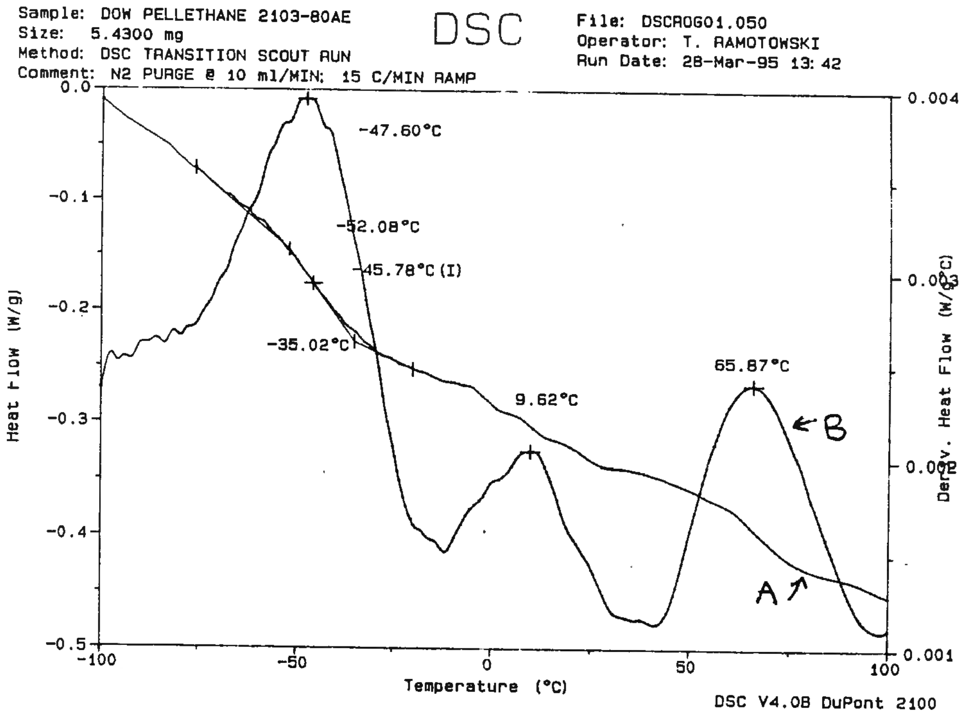


Figure 2: DSC thermogram from -100°C to +100°C for Dow Pellethane 2351-85AE elastomer. Curve (A) is the DSC heat flow trace; curve (B) is the first derivative of the DSC heat flow trace with respect to temperature. The computer software calculated T_g is indicated by a Roman numeral "I" in parentheses. A few other minor thermal events are also visible.

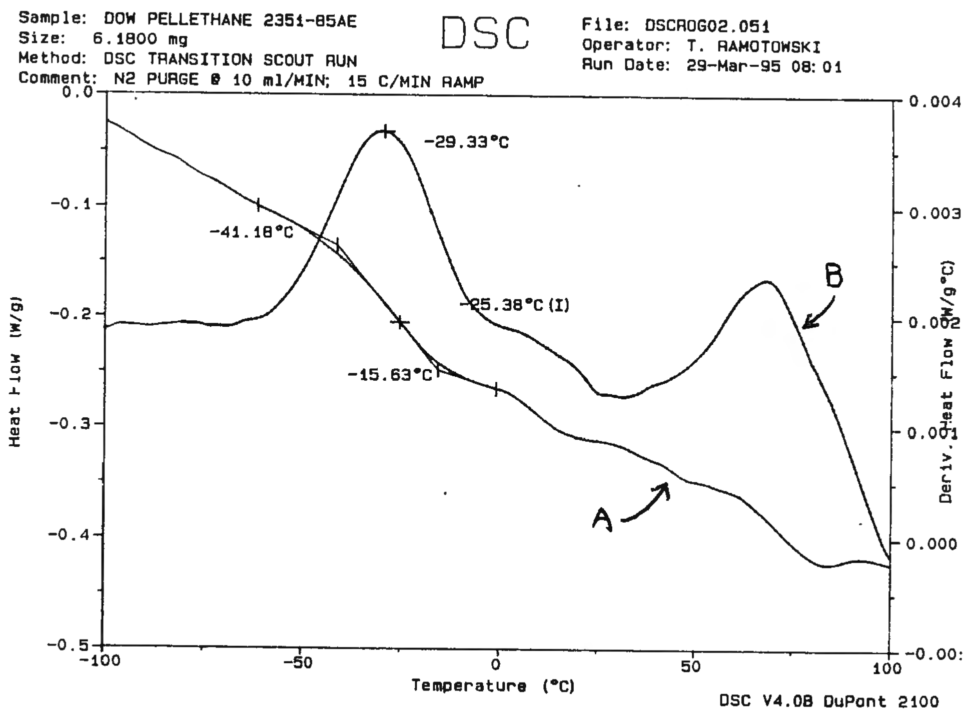
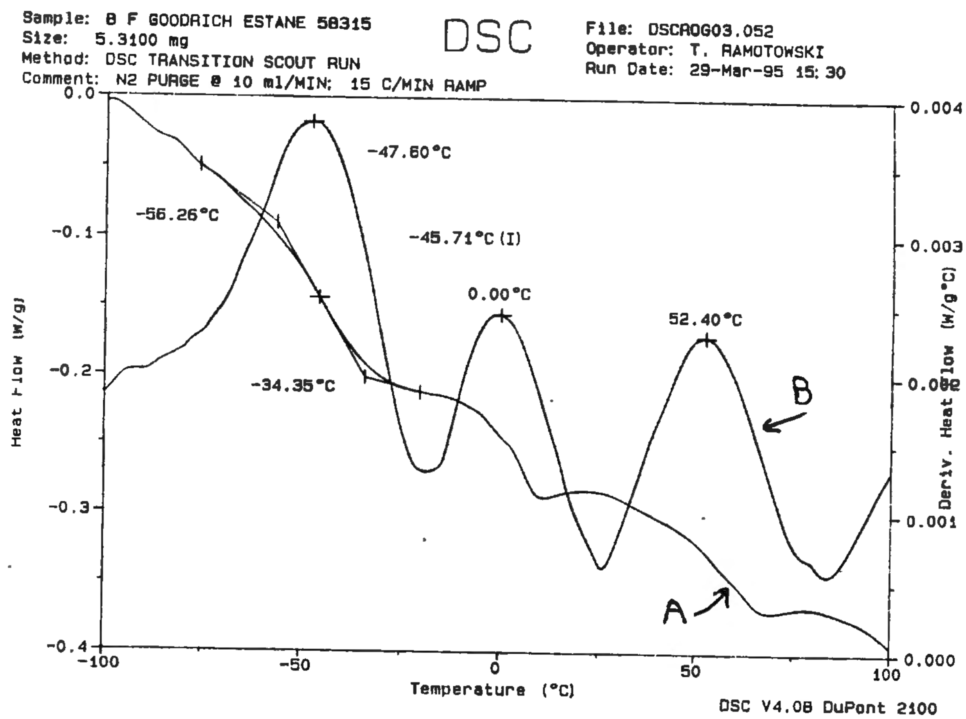


Figure 3: DSC thermogram from -100°C to +100°C for B. F. Goodrich Estane 58315 elastomer. Curve (A) is the DSC heat flow trace; curve (B) is the first derivative of the DSC heat flow trace with respect to temperature. The computer software calculated T_g is indicated by a Roman numeral "I" in parentheses. A few other minor thermal events are also visible.



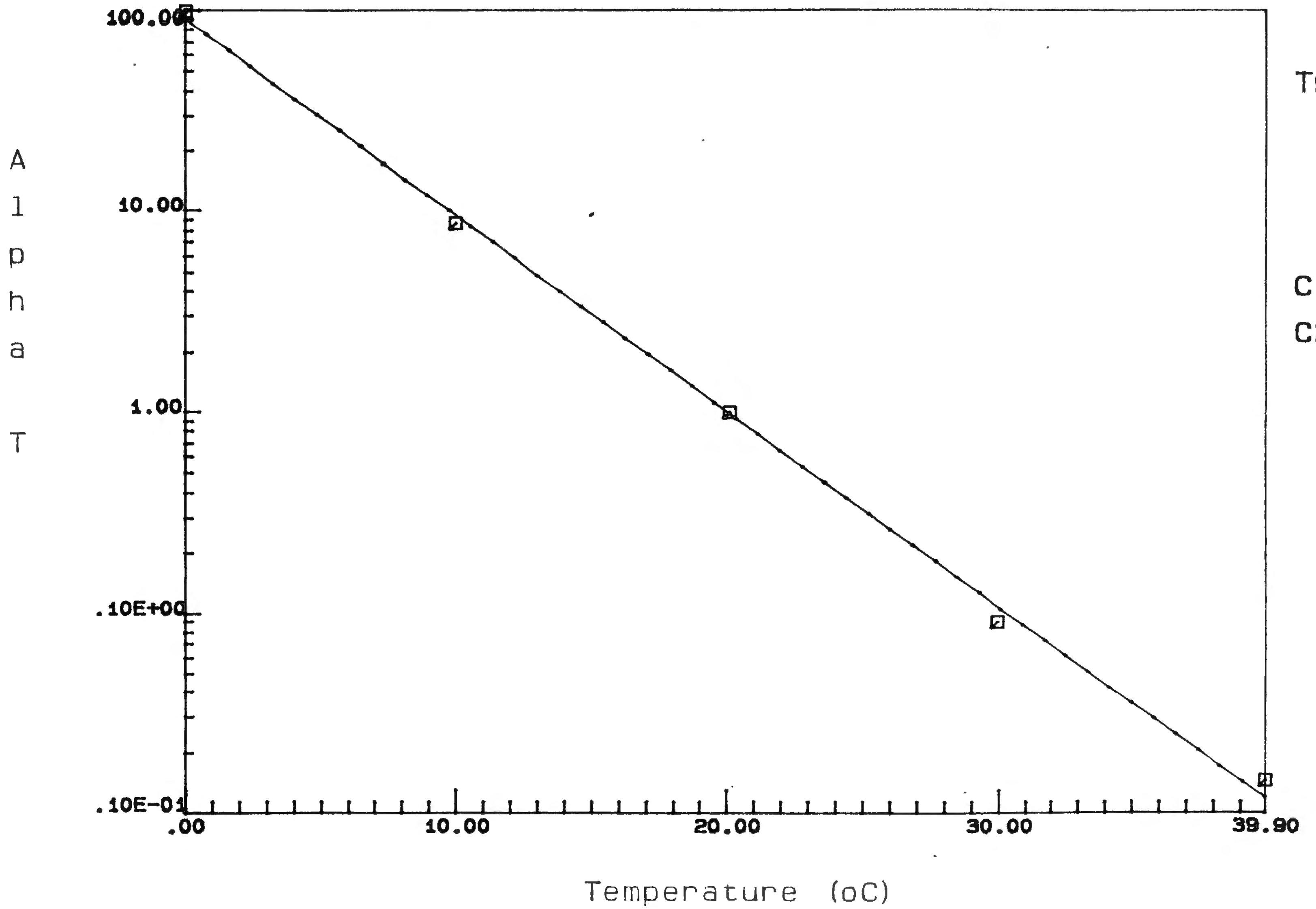
Appendix C

E' Master Curve and Shift Factor Tabular Data for 2103-80AE Pellethane

File : 2103t2 * TRACTION-COMPRESSION * Date . 3/24/95

Sample .

Sizes : Height (mm) : 1.7 Thickn. (mm) : 3.4 Width (mm) . 3.3



Tref (oC)
20.10

C1 355.08
C2 3650.82

METRAVIB

File : 214Tt2 * TRACTION-COMPRESSION * Date : 3/24/95

Sample :

Sizes : Height (mm) : 1.68
Thickn. (mm) : 3.42
Width (mm) : 3.33

REGULATION : DYNAMIC (1E-6M) : 5.00
STATIC (1E-6M) : NO

REFERENCE TEMPERATURE (OC) : 20.10

WLF COEFFICIENTS C1 AND C2 : .35508E+03 .36508E+04

TEMPERATURE (OC)	ALPHA(T) MEA.	ALPHA(T) CAL.
.0	.99232E+02	.92421E+02
10.0	.87532E+01	.96619E+01
20.1	.10000E+01	.10000E+01
30.0	.91610E-01	.10958E+00
39.9	.14685E-01	.12151E-01

File : 2103t2 * TRACTION-COMPRESSION * Date : 3/24/95

Sample :

Sizes : Height (mm) : 1.68
Thickn. (mm) : 3.42
Width (mm) : 3.33

REGULATION : DYNAMIC (1E-6M) : 5.00
STATIC (1E-6M) : NO

** MASTER CURVE **

FERENCE TEMPERATURE : 20.10 oC

POLYNOMIAL COEFFICIENTS (LOG10-LOG10 IN INCREASING ORDER) :

.78666E+01 * .82420E-01 * .12960E-01 * -.22100E-02 * .27864E-03 *

T(OC)	F(HZ)	F*ALPHA(T) (HZ)	E' (N/M2) MEA.	E' (N/M2) CAL.
.0	5.0	.49616E+03	.14392E+09	.14269E+09
	54.5	.54071E+04	.19023E+09	.19680E+09
	104.0	.10319E+05	.21719E+09	.21658E+09
	153.6	.15238E+05	.22705E+09	.22998E+09
	202.9	.20136E+05	.24225E+09	.24035E+09
	252.5	.25059E+05	.25156E+09	.24899E+09
	301.9	.29961E+05	.25819E+09	.25641E+09
	351.1	.34843E+05	.26375E+09	.26294E+09
	400.6	.39756E+05	.26803E+09	.26887E+09
	451.3	.44780E+05	.27291E+09	.27438E+09
	500.0	.49616E+05	.27817E+09	.27928E+09
10.0	5.0	.43766E+02	.10902E+09	.10691E+09
	54.5	.47696E+03	.13595E+09	.14198E+09
	104.0	.91027E+03	.15343E+09	.15420E+09
	153.6	.13442E+04	.15670E+09	.16230E+09
	202.9	.17762E+04	.17293E+09	.16847E+09
	252.5	.22104E+04	.17569E+09	.17355E+09
	301.9	.26429E+04	.17944E+09	.17786E+09
	351.1	.30735E+04	.18264E+09	.18163E+09
	400.6	.35069E+04	.18552E+09	.18501E+09
	451.3	.39500E+04	.18900E+09	.18815E+09
	500.0	.43766E+04	.19208E+09	.19091E+09
20.1	5.0	.50000E+01	.87754E+08	.85087E+08
	54.5	.54490E+02	.10463E+09	.10959E+09
	104.0	.10399E+03	.11600E+09	.11805E+09
	153.6	.15356E+03	.12201E+09	.12360E+09
	202.9	.20292E+03	.12976E+09	.12780E+09
	252.5	.25253E+03	.13229E+09	.13123E+09
	301.9	.30193E+03	.13496E+09	.13414E+09

T(OC)	F(HZ)	F*ALPHA(T) (HZ)	E' (N/M2) MEA.	E' (N/M2) CAL.
20.1	351.1	.35112E+03	.13759E+09	.13666E+09
	400.6	.40064E+03	.13982E+09	.13891E+09
	451.3	.45126E+03	.14225E+09	.14100E+09
	500.0	.50000E+03	.14441E+09	.14283E+09
30.0	5.0	.45805E+00	.71227E+08	.69222E+08
	54.5	.49918E+01	.81365E+08	.85074E+08
	104.0	.95269E+01	.88545E+08	.90761E+08
	153.6	.14068E+02	.97739E+08	.94509E+08
	202.9	.18590E+02	.98042E+08	.97344E+08
	252.5	.23134E+02	.99831E+08	.99662E+08
	301.9	.27660E+02	.10181E+09	.10162E+09
	351.1	.32167E+02	.10366E+09	.10332E+09
	400.6	.36703E+02	.10517E+09	.10484E+09
	451.3	.41340E+02	.10669E+09	.10623E+09
	500.0	.45805E+02	.10771E+09	.10746E+09
39.9	5.0	.73423E-01	.62203E+08	
	54.5	.80017E+00	.69353E+08	.72236E+08
	104.0	.15271E+01	.74005E+08	.76241E+08
	153.6	.22550E+01	.81472E+08	.78930E+08
	202.9	.29798E+01	.81702E+08	.80982E+08
	252.5	.37083E+01	.82964E+08	.82669E+08
	301.9	.44338E+01	.84253E+08	.84099E+08
	351.1	.51561E+01	.85528E+08	.85343E+08
	400.6	.58833E+01	.86706E+08	.86459E+08
	451.3	.66267E+01	.87721E+08	.87488E+08
	500.0	.73423E+01	.88411E+08	.88392E+08

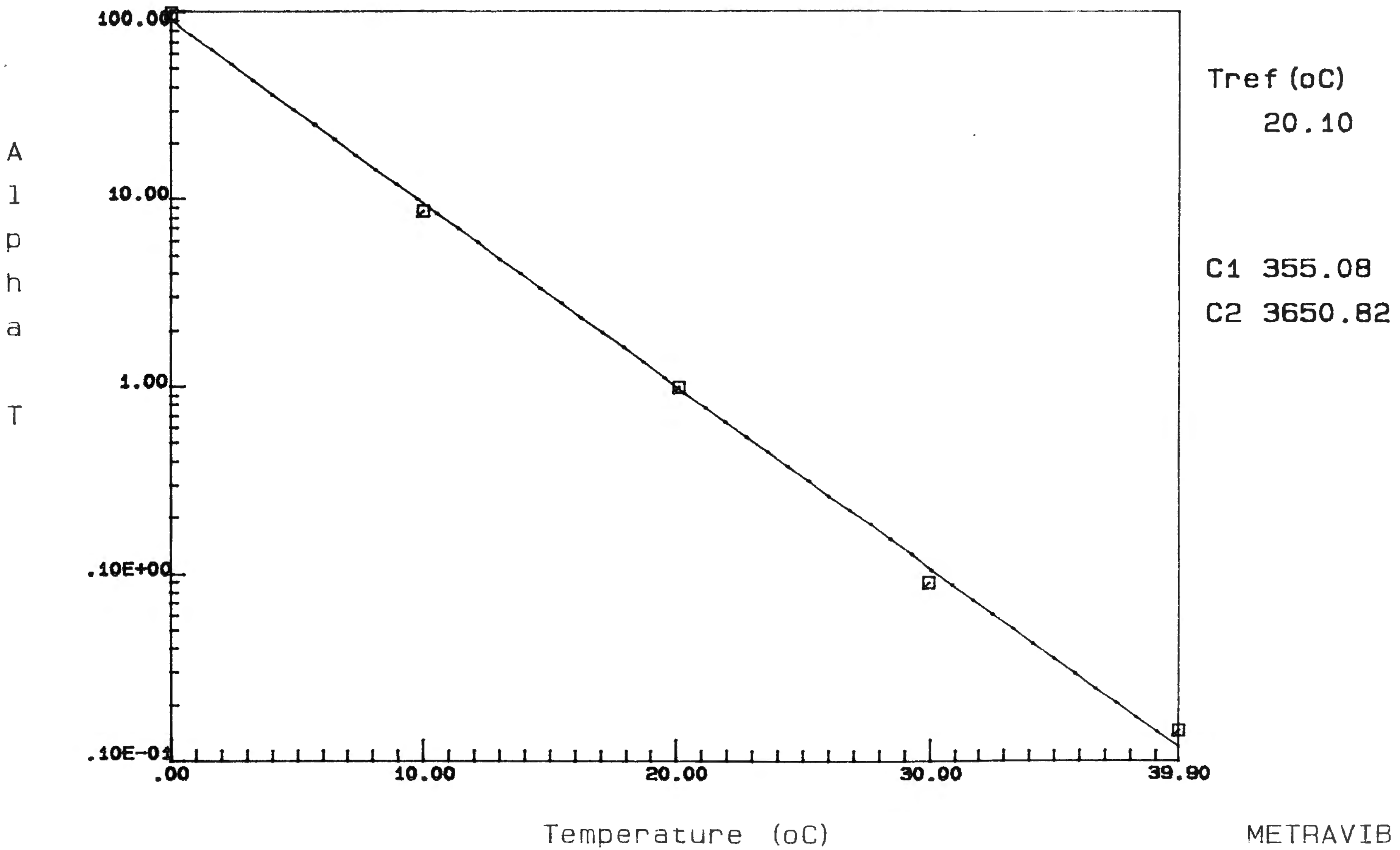
Appendix D

Tan Delta Master Curve and Shift Factor Tabular Data for 2103-80AE Pellethane

File : 2103t2 * TRACTION-COMPRESSION * Date . 3/24/95

Sample :

Sizes : Height (mm) . 1.7 Thickn. (mm) : 3.4 Width (mm) . 3.3



File : 21[illegible] * TRACTION-COMPRESSION * Date : 3/24/95

Sample :

Sizes : Height (mm) : 1.68
Thickn. (mm) : 3.42
Width (mm) : 3.33

REGULATION : DYNAMIC (1E-6M) : 5.00
STATIC (1E-6M) : NO

REFERENCE TEMPERATURE (OC) : 20.10

WLF COEFFICIENTS C1 AND C2 : .35508E+03 .36508E+04

TEMPERATURE (OC)	ALPHA(T) MEA.	ALPHA(T) CAL.
.0	.99232E+02	.92421E+02
10.0	.87532E+01	.96619E+01
20.1	.10000E+01	.10000E+01
30.0	.91610E-01	.10958E+00
39.9	.14685E-01	.12151E-01

File : 21[illegible]t[illegible] * TRACTION-COMPRESSION * Date : 3/24/95

Sample :

Sizes : Height (mm) : 1.68
Thickn. (mm) : 3.42
Width (mm) : 3.33

REGULATION : DYNAMIC (1E-6M) : 5.00
STATIC (1E-6M) : NO

** MASTER CURVE **

FERENCE TEMPERATURE : 20.10 oC

POLYNOMIAL COEFFICIENTS (LOG10-LOG10 IN INCREASING ORDER) :

-.93464E+00 * .14678E+00 * -.24224E-01 * .37344E-02 * -.32407E-03 *

T(OC)	F(HZ)	F*ALPHA(T) (HZ)	TAN DELTA MEA.	TAN DELTA CAL.
.0	5.0	.49616E+03	.18035E+00	.21930E+00
	54.5	.54071E+04	.23454E+00	.25531E+00
	104.0	.10319E+05	.25312E+00	.26401E+00
	153.6	.15238E+05	.27331E+00	.26890E+00
	202.9	.20136E+05	.30746E+00	.27221E+00
	252.5	.25059E+05	.27437E+00	.27468E+00
	301.9	.29961E+05	.27217E+00	.27661E+00
	351.1	.34843E+05	.27378E+00	.27817E+00
	400.6	.39756E+05	.27477E+00	.27948E+00
	451.3	.44780E+05	.27727E+00	.28061E+00
	500.0	.49616E+05	.27892E+00	.28156E+00
10.0	5.0	.43766E+02	.14323E+00	.17995E+00
	54.5	.47696E+03	.19805E+00	.21868E+00
	104.0	.91027E+03	.22139E+00	.22883E+00
	153.6	.13442E+04	.26661E+00	.23484E+00
	202.9	.17762E+04	.24755E+00	.23908E+00
	252.5	.22104E+04	.24270E+00	.24236E+00
	301.9	.26429E+04	.24503E+00	.24502E+00
	351.1	.30735E+04	.24825E+00	.24723E+00
	400.6	.35069E+04	.25053E+00	.24915E+00
	451.3	.39500E+04	.25404E+00	.25086E+00
	500.0	.43766E+04	.25760E+00	.25233E+00
20.1	5.0	.50000E+01	.11294E+00	.14365E+00
	54.5	.54490E+02	.16191E+00	.18357E+00
	104.0	.10399E+03	.18639E+00	.19416E+00
	153.6	.15356E+03	.27766E+00	.20049E+00
	202.9	.20292E+03	.20355E+00	.20500E+00
	252.5	.25253E+03	.20631E+00	.20852E+00
	301.9	.30193E+03	.20969E+00	.21139E+00

T(OC)	F(HZ)	F*ALPHA(T) (HZ)	TAN DELTA MEA.	TAN DELTA CAL.
20.1	351.1	.35112E+03	.21404E+00	.21380E+00
	400.6	.40064E+03	.21708E+00	.21591E+00
	451.3	.45126E+03	.22096E+00	.21780E+00
	500.0	.50000E+03	.22600E+00	.21942E+00
30.0	5.0	.45805E+00	.88641E-01	.10296E+00
	54.5	.49918E+01	.12856E+00	.14363E+00
	104.0	.95269E+01	.15303E+00	.15454E+00
	153.6	.14068E+02	.18761E+00	.16108E+00
	202.9	.18590E+02	.16455E+00	.16574E+00
	252.5	.23134E+02	.16918E+00	.16939E+00
	301.9	.27660E+02	.17270E+00	.17236E+00
	351.1	.32167E+02	.17663E+00	.17486E+00
	400.6	.36703E+02	.17976E+00	.17705E+00
	451.3	.41340E+02	.18337E+00	.17901E+00
	500.0	.45805E+02	.18962E+00	.18071E+00
39.9	5.0	.73423E-01	.75617E-01	
	54.5	.80017E+00	.10842E+00	.11244E+00
	104.0	.15271E+01	.13356E+00	.12347E+00
	153.6	.22550E+01	.14864E+00	.13012E+00
	202.9	.29798E+01	.14008E+00	.13486E+00
	252.5	.37083E+01	.14454E+00	.13858E+00
	301.9	.44338E+01	.14735E+00	.14162E+00
	351.1	.51561E+01	.15117E+00	.14418E+00
	400.6	.58833E+01	.15406E+00	.14641E+00
	451.3	.66267E+01	.15792E+00	.14842E+00
	500.0	.73423E+01	.16498E+00	.15015E+00

Appendix E

Dynamic Tension Tabular Data for 2351-85AE Pellethane

VISCOANALYSEUR TO :

METRAVIB
instruments

MEASUREMENT FILE...................... MV2351t3

DATE................................ 3/ 29/ 95

SAMPLE REFERENCE...................... 2351-85AE Pellethane

TEST PERFORMED IN : TRACTION COMPRESSION

SAMPLE FEATURES :

- SHAPE...............................		PARALLELEPIPEDIC
- HEIGHT..............................	4.17	mm
- THICKNESS...........................	3.87	mm
- WIDTH...............................	4.01	mm

MEASUREMENT CONDITIONS :

- SCANNING IN TEMPERATURE.............	-40.0 -	40.0	oC
- SCANNING IN FREQUENCY...............	5.0 -	500.0	HERTZ
- REGULATION IN DISPLACEMENT..........		5.0	MICRON
- PRESTRAIN REGULATION................			NO

REMARKS :

TEST PERFORMED BY :

SERVICE :

SAMPLE REFERENCE........................ 2351-85AE Pellethane

TEMPERATURE NUMBER.................... 1

- STARTING TEMPERATURE................ 23.5 oC
- VARIATION RATE OF TEMPERATURE....... 5.0 oC/mn
- STABILIZATION TIME IN TEMPERATURE... 15 mn
- FINAL TEMPERATURE................... -40.0 oC

No	FREQUENCY HERTZ	E' N/m2	E" N/m2	E N/m2	TAN. DELTA
1	5.0	.249E+10	.955E+08	.249E+10	.384E-01
2	54.5	.261E+10	.909E+08	.261E+10	.349E-01
3	104.0	.263E+10	.106E+09	.263E+10	.403E-01
4	153.6	.266E+10	.114E+09	.266E+10	.428E-01
5	202.9	.269E+10	.109E+09	.269E+10	.405E-01
6	252.5	.270E+10	.108E+09	.270E+10	.401E-01
7	301.9	.273E+10	.106E+09	.273E+10	.387E-01
8	351.1	.275E+10	.107E+09	.275E+10	.389E-01
9	400.6	.275E+10	.108E+09	.276E+10	.392E-01
10	451.3	.278E+10	.108E+09	.278E+10	.390E-01
11	500.0	.281E+10	.880E+08	.281E+10	.314E-01

SAMPLE REFERENCE......................... 2351-85AE Pellethane

TEMPERATURE NUMBER.................... 2

- STARTING TEMPERATURE................. -40.0 oC
- VARIATION RATE OF TEMPERATURE....... 5.0 oC/mn
- STABILIZATION TIME IN TEMPERATURE... 15 mn
- FINAL TEMPERATURE................... -29.9 oC

No	FREQUENCY HERTZ	E' N/m2	E" N/m2	E N/m2	TAN. DELTA
1	5.0	.184E+10	.183E+09	.185E+10	.997E-01
2	54.5	.207E+10	.159E+09	.208E+10	.768E-01
3	104.0	.212E+10	.166E+09	.213E+10	.785E-01
4	153.6	.216E+10	.171E+09	.217E+10	.790E-01
5	202.9	.219E+10	.165E+09	.219E+10	.752E-01
6	252.5	.221E+10	.166E+09	.222E+10	.753E-01
7	301.9	.223E+10	.163E+09	.224E+10	.731E-01
8	351.1	.225E+10	.172E+09	.226E+10	.765E-01
9	400.6	.228E+10	.165E+09	.228E+10	.724E-01
10	451.3	.231E+10	.165E+09	.232E+10	.716E-01
11	500.0	.236E+10	.150E+09	.237E+10	.633E-01

SAMPLE REFERENCE........................ 2351-85AE Pellethane

TEMPERATURE NUMBER.................... 3

- STARTING TEMPERATURE................ -29.9 oC
- VARIATION RATE OF TEMPERATURE....... 5.0 oC/mn
- STABILIZATION TIME IN TEMPERATURE... 15 mn
- FINAL TEMPERATURE................... -20.0 oC

No	FREQUENCY HERTZ	E' N/m2	E" N/m2	E N/m2	TAN. DELTA
1	5.0	.101E+10	.234E+09	.104E+10	.231
2	54.5	.136E+10	.240E+09	.138E+10	.176
3	104.0	.143E+10	.248E+09	.145E+10	.173
4	153.6	.147E+10	.252E+09	.149E+10	.172
5	202.9	.151E+10	.247E+09	.153E+10	.163
6	252.5	.152E+10	.249E+09	.154E+10	.163
7	301.9	.152E+10	.254E+09	.154E+10	.167
8	351.1	.157E+10	.254E+09	.159E+10	.162
9	400.6	.161E+10	.252E+09	.163E+10	.156
10	451.3	.161E+10	.257E+09	.163E+10	.160
11	500.0	.158E+10	.259E+09	.160E+10	.164

SAMPLE REFERENCE........................ 2351-85AE Pellethane

TEMPERATURE NUMBER.................... 4

- STARTING TEMPERATURE................. -20.0 oC
- VARIATION RATE OF TEMPERATURE....... 5.0 oC/mn
- STABILIZATION TIME IN TEMPERATURE... 15 mn
- FINAL TEMPERATURE................... -10.0 oC

No	FREQUENCY HERTZ	E´ N/m2	E" N/m2	E N/m2	TAN. DELTA
1	5.0	.428E+09	.149E+09	.453E+09	.349
2	54.5	.689E+09	.217E+09	.722E+09	.315
3	104.0	.794E+09	.239E+09	.830E+09	.300
4	153.6	.824E+09	.248E+09	.861E+09	.301
5	202.9	.846E+09	.250E+09	.882E+09	.296
6	252.5	.856E+09	.257E+09	.893E+09	.300
7	301.9	.863E+09	.258E+09	.901E+09	.300
8	351.1	.865E+09	.259E+09	.903E+09	.299
9	400.6	.891E+09	.263E+09	.929E+09	.296
10	451.3	.915E+09	.268E+09	.954E+09	.293
11	500.0	.882E+09	.267E+09	.922E+09	.303

SAMPLE REFERENCE........................ 2351-85AE Pellethane

TEMPERATURE NUMBER..................... 5

- STARTING TEMPERATURE................. -10.0 oC
- VARIATION RATE OF TEMPERATURE....... 5.0 oC/mn
- STABILIZATION TIME IN TEMPERATURE... 15 mn
- FINAL TEMPERATURE................... .0 oC

No	FREQUENCY HERTZ	E' N/m2	E" N/m2	E N/m2	TAN. DELTA'
1	5.0	.202E+09	.645E+08	.212E+09	.320
2	54.5	.334E+09	.127E+09	.357E+09	.379
3	104.0	.379E+09	.148E+09	.407E+09	.389
4	153.6	.413E+09	.163E+09	.443E+09	.395
5	202.9	.437E+09	.172E+09	.470E+09	.394
6	252.5	.451E+09	.176E+09	.484E+09	.390
7	301.9	.471E+09	.182E+09	.505E+09	.388
8	351.1	.473E+09	.184E+09	.508E+09	.390
9	400.6	.487E+09	.189E+09	.523E+09	.389
10	451.3	.482E+09	.190E+09	.518E+09	.394
11	500.0	.501E+09	.197E+09	.539E+09	.392

SAMPLE REFERENCE........................ 2351-85AE Pellethane

TEMPERATURE NUMBER.................... 6

- STARTING TEMPERATURE................ .0 oC
- VARIATION RATE OF TEMPERATURE....... 5.0 oC/mn
- STABILIZATION TIME IN TEMPERATURE... 15 mn
- FINAL TEMPERATURE................... 10.1 oC

No	FREQUENCY HERTZ	E' N/m2	E" N/m2	E N/m2	TAN. DELTA
1	5.0	.128E+09	.286E+08	.131E+09	.223
2	54.5	.184E+09	.610E+08	.194E+09	.331
3	104.0	.211E+09	.771E+08	.225E+09	.365
4	153.6	.226E+09	.877E+08	.242E+09	.389
5	202.9	.240E+09	.926E+08	.257E+09	.386
6	252.5	.254E+09	.994E+08	.273E+09	.391
7	301.9	.263E+09	.104E+09	.283E+09	.396
8	351.1	.269E+09	.108E+09	.289E+09	.400
9	400.6	.276E+09	.111E+09	.297E+09	.404
10	451.3	.281E+09	.115E+09	.303E+09	.409
11	500.0	.283E+09	.117E+09	.306E+09	.414

SAMPLE REFERENCE........................ 2351-85AE Pellethane

TEMPERATURE NUMBEF.................... 7

- STARTING TEMPERATURE................ 10.1 oC
- VARIATION RATE OF TEMPERATURE....... 5.0 oC/mn
- STABILIZATION TIME IN TEMPERATURE... 15 mn
- FINAL TEMPERATURE................... 20.0 oC

No	FREQUENCY HERTZ	E' N/m2	E" N/m2	E N/m2	TAN. DELTA
1	5.0	.988E+08	.149E+08	.999E+08	.151
2	54.5	.127E+09	.311E+08	.131E+09	.244
3	104.0	.140E+09	.397E+08	.145E+09	.284
4	153.6	.151E+09	.469E+08	.158E+09	.311
5	202.9	.158E+09	.498E+08	.166E+09	.315
6	252.5	.163E+09	.531E+08	.172E+09	.325
7	301.9	.169E+09	.565E+08	.178E+09	.335
8	351.1	.172E+09	.585E+08	.181E+09	.341
9	400.6	.177E+09	.617E+08	.187E+09	.349
10	451.3	.179E+09	.640E+08	.190E+09	.357
11	500.0	.183E+09	.676E+08	.195E+09	.369

SAMPLE REFERENCE........................ 2351-85AE Pellethane

TEMPERATURE NUMBER.................... 8

- STARTING TEMPERATURE................ 20.0 oC
- VARIATION RATE OF TEMPERATURE....... 5.0 oC/mn
- STABILIZATION TIME IN TEMPERATURE... 15 mn
- FINAL TEMPERATURE................... 30.1 oC

No	FREQUENCY HERTZ	E' N/m2	E" N/m2	E N/m2	TAN. DELTA
1	5.0	.808E+08	.871E+07	.813E+08	.108
2	54.5	.961E+08	.165E+08	.975E+08	.171
3	104.0	.101E+09	.212E+08	.104E+09	.209
4	153.6	.108E+09	.243E+08	.111E+09	.225
5	202.9	.112E+09	.259E+08	.115E+09	.232
6	252.5	.115E+09	.277E+08	.118E+09	.241
7	301.9	.118E+09	.295E+08	.122E+09	.250
8	351.1	.120E+09	.313E+08	.124E+09	.260
9	400.6	.122E+09	.324E+08	.126E+09	.266
10	451.3	.123E+09	.343E+08	.128E+09	.278
11	500.0	.124E+09	.362E+08	.129E+09	.292

SAMPLE REFERENCE........................ 2351-85AE Pellethane

TEMPERATURE NUMBER.................... 9

- STARTING TEMPERATURE................ 30.1 oC
- VARIATION RATE OF TEMPERATURE....... 5.0 oC/mn
- STABILIZATION TIME IN TEMPERATURE... 15 mn
- FINAL TEMPERATURE................... 40.0 oC

No	FREQUENCY HERTZ	E' N/m2	E" N/m2	E N/m2	TAN. DELTA
1	5.0	.710E+08	.625E+07	.713E+08	.880E-01
2	54.5	.817E+08	.109E+08	.825E+08	.134
3	104.0	.848E+08	.151E+08	.861E+08	.178
4	153.6	.892E+08	.155E+08	.906E+08	.174
5	202.9	.921E+08	.166E+08	.935E+08	.180
6	252.5	.940E+08	.178E+08	.957E+08	.189
7	301.9	.959E+08	.187E+08	.977E+08	.195
8	351.1	.971E+08	.196E+08	.991E+08	.202
9	400.6	.985E+08	.205E+08	.101E+09	.208
10	451.3	.993E+08	.218E+08	.102E+09	.219
11	500.0	.982E+08	.226E+08	.101E+09	.230

Appendix F

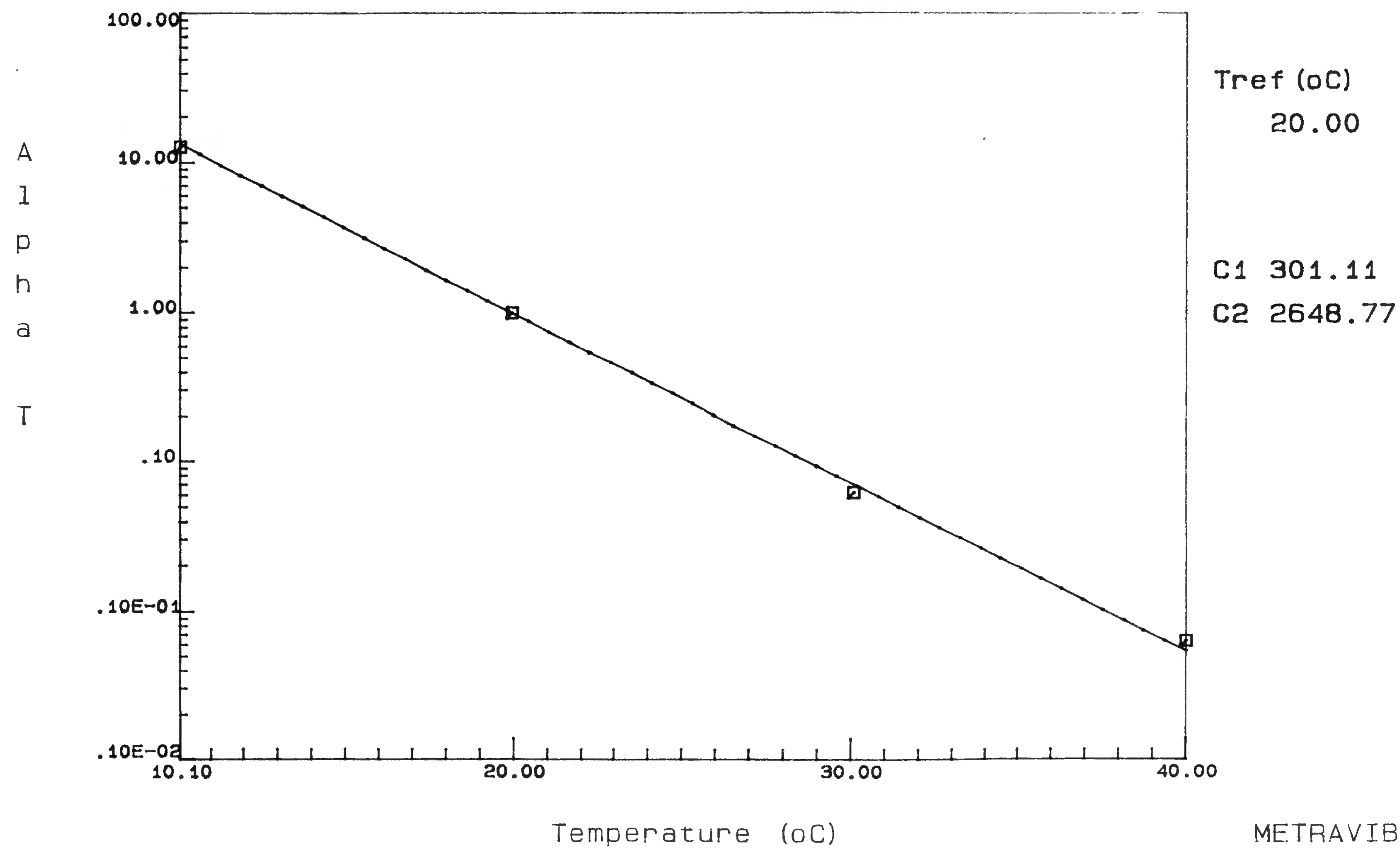
E' Master Curve and Shift Factor Tabular Data for 2351-85AE Pellethane

F-2

File : 2351t3 * TRACTION-COMPRESSION * Date . 3/30/95

Sample : 2351-85AE Pellethane

Sizes : Height (mm) . 4.2 Thickn. (mm) : 3.9 Width (mm) : 4.0



File : 2351t3 * TRACTION-COMPRESSION * Date : 3/30/93

Sample : 2351-85AE Pellethane

Sizes : Height (mm) : 4.17
Thickn. (mm) : 3.87
Width (mm) : 4.01

REGULATION : DYNAMIC (1E-6M) : 5.00
STATIC (1E-6M) : NO

REFERENCE TEMPERATURE (OC) : 20.00

WLF COEFFICIENTS C1 AND C2 : .30111E+03 .26488E+04

TEMPERATURE (OC)	ALPHA(T) MEA.	ALPHA(T) CAL.
10.1	.12947E+02	.13478E+02
20.0	.10000E+01	.10000E+01
30.1	.63054E-01	.71814E-01
40.0	.64879E-02	.55396E-02

File : 2351t3 * TRACTION-COMPRESSION * Date : 3/30/95

Sample : 2351-85AE Pellethane

Sizes : Height (mm) : 4.17
Thickn. (mm) : 3.87
Width (mm) : 4.01

REGULATION : DYNAMIC (1E-6M) : 5.00
STATIC (1E-6M) : NO

** MASTER CURVE **

FERENCE TEMPERATURE : 20.00 oC

POLYNOMIAL COEFFICIENTS (LOG10-LOG10 IN INCREASING ORDER) :

.79239E+01 * .83797E-01 * .12460E-01 * .11769E-02 * -.57869E-04 *

T(OC)	F(HZ)	F*ALPHA(T) (HZ)	E' (N/M2) MEA.	E' (N/M2) CAL.
10.1	5.0	.64735E+02	.13284E+09	.13271E+09
	54.5	.70549E+03	.19089E+09	.19368E+09
	104.0	.13464E+04	.21882E+09	.21809E+09
	153.6	.19882E+04	.23355E+09	.23510E+09
	202.9	.26272E+04	.24824E+09	.24848E+09
	252.5	.32695E+04	.26295E+09	.25975E+09
	301.9	.39091E+04	.27205E+09	.26952E+09
	351.1	.45460E+04	.27813E+09	.27818E+09
	400.6	.51871E+04	.28553E+09	.28607E+09
	451.3	.58425E+04	.29047E+09	
	500.0	.64735E+04	.29296E+09	
20.0	5.0	.50000E+01	.98817E+08	.97486E+08
	54.5	.54490E+02	.12727E+09	.12960E+09
	104.0	.10399E+03	.13963E+09	.14201E+09
	153.6	.15356E+03	.15086E+09	.15053E+09
	202.9	.20292E+03	.15791E+09	.15718E+09
	252.5	.25253E+03	.16322E+09	.16274E+09
	301.9	.30193E+03	.16899E+09	.16753E+09
	351.1	.35112E+03	.17164E+09	.17176E+09
	400.6	.40064E+03	.17685E+09	.17559E+09
	451.3	.45126E+03	.17928E+09	.17917E+09
	500.0	.50000E+03	.18294E+09	.18235E+09
30.1	5.0	.31527E+00	.78099E+08	.76713E+08
	54.5	.34358E+01	.92866E+08	.93880E+08
	104.0	.65572E+01	.98051E+08	.10029E+09
	153.6	.96828E+01	.10450E+09	.10464E+09
	202.9	.12795E+02	.10800E+09	.10800E+09
	252.5	.15923E+02	.11085E+09	.11080E+09
	301.9	.19038E+02	.11409E+09	.11320E+09

T(OC)	F(HZ)	F*ALPHA(T) (HZ)	E' (N/M2) MEA.	E' (N/M2) CAL.
30.1	351.1	.22140E+02	.11626E+09	.11530E+09
	400.6	.25262E+02	.11769E+09	.11721E+09
	451.3	.28454E+02	.11928E+09	.11898E+09
	500.0	.31527E+02	.11984E+09	.12054E+09
40.0	5.0	.32440E-01	.66491E+08	
	54.5	.35353E+00	.76512E+08	.77355E+08
	104.0	.67470E+00	.79359E+08	.81271E+08
	153.6	.99630E+00	.83512E+08	.83900E+08
	202.9	.13165E+01	.86169E+08	.85918E+08
	252.5	.16384E+01	.87997E+08	.87589E+08
	301.9	.19589E+01	.89758E+08	.89014E+08
	351.1	.22781E+01	.90913E+08	.90262E+08
	400.6	.25993E+01	.92212E+08	.91388E+08
	451.3	.29278E+01	.92910E+08	.92431E+08
	500.0	.32440E+01	.91959E+08	.93353E+08

Appendix G

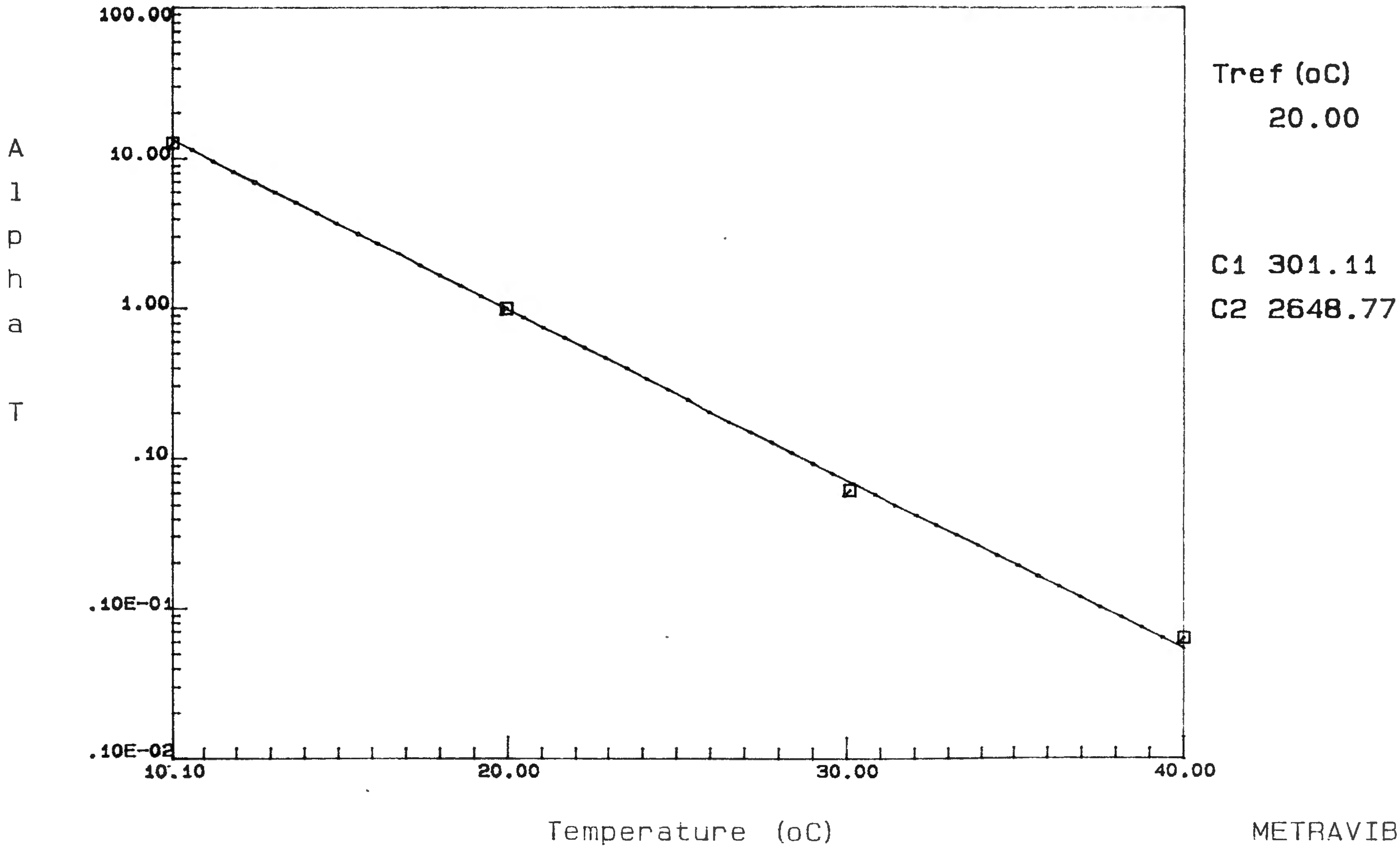
Tan Delta Master Curve and Shift Factor Tabular Data for 2351-85AE Pellethane

G-2

File : 2351t3 * TRACTION-COMPRESSION * Date . 3/30/95

Sample : 2351-85AE Pellethane

Sizes : Height (mm) . 4.2 Thickn. (mm) . 3.9 Width (mm) . 4.0



File : 2351t3 * TRACTION-COMPRESSION * Date : 3/30/95

Sample : 2351-85AE Pellethane

Sizes : Height (mm) : 4.17
Thickn. (mm) : 3.87
Width (mm) : 4.01

REGULATION : DYNAMIC (1E-6M) : 5.00
STATIC (1E-6M) : NO

REFERENCE TEMPERATURE (OC) : 20.00

WLF COEFFICIENTS C1 AND C2 : .30111E+03 .26488E+04

TEMPERATURE (OC)	ALPHA(T) MEA.	ALPHA(T) CAL.
10.1	.12947E+02	.13478E+02
20.0	.10000E+01	.10000E+01
30.1	.63054E-01	.71814E-01
40.0	.64879E-02	.55396E-02

File : 2351t3 * TRACTION-COMPRESSION * Date : 3/30/95

Sample : 2351-85AE Pellethane

Sizes : Height (mm) : 4.17
Thickn. (mm) : 3.87
Width (mm) : 4.01

REGULATION : DYNAMIC (1E-6M) : 5.00
STATIC (1E-6M) : NO

** MASTER CURVE **

FERENCE TEMPERATURE : 20.00 oC

POLYNOMIAL COEFFICIENTS (LOG10-LOG10 IN INCREASING ORDER) :

-.78431E+00 * .14566E+00 * -.20415E-01 * .58856E-02 * -.89002E-03 *

T(OC)	F(HZ)	F*ALPHA(T) (HZ)	TAN DELTA MEA.	TAN DELTA CAL.
10.1	5.0	.64735E+02	.22288E+00	.27411E+00
	54.5	.70549E+03	.33082E+00	.34865E+00
	104.0	.13464E+04	.36473E+00	.36862E+00
	153.6	.19882E+04	.38885E+00	.38009E+00
	202.9	.26272E+04	.38612E+00	.38788E+00
	252.5	.32695E+04	.39128E+00	.39369E+00
	301.9	.39091E+04	.39620E+00	.39820E+00
	351.1	.45460E+04	.40020E+00	.40183E+00
	400.6	.51871E+04	.40358E+00	
	451.3	.58425E+04	.40882E+00	
	500.0	.64735E+04	.41440E+00	
20.0	5.0	.50000E+01	.15073E+00	.20386E+00
	54.5	.54490E+02	.24434E+00	.26901E+00
	104.0	.10399E+03	.28443E+00	.28840E+00
	153.6	.15356E+03	.31108E+00	.30042E+00
	202.9	.20292E+03	.31542E+00	.30914E+00
	252.5	.25253E+03	.32528E+00	.31604E+00
	301.9	.30193E+03	.33461E+00	.32171E+00
	351.1	.35112E+03	.34057E+00	.32650E+00
	400.6	.40064E+03	.34883E+00	.33070E+00
	451.3	.45126E+03	.35700E+00	.33449E+00
	500.0	.50000E+03	.36946E+00	.33775E+00
30.1	5.0	.31527E+00	.10786E+00	.13701E+00
	54.5	.34358E+01	.17140E+00	.19442E+00
	104.0	.65572E+01	.20949E+00	.21079E+00
	153.6	.96828E+01	.22503E+00	.22093E+00
	202.9	.12795E+02	.23219E+00	.22833E+00
	252.5	.15923E+02	.24130E+00	.23423E+00
	301.9	.19038E+02	.25018E+00	.23911E+00

T(OC)	F(HZ)	F*ALPHA(T) (HZ)	TAN DELTA MEA.	TAN DELTA CAL.
30.1	351.1	.22140E+02	.25998E+00	.24327E+00
	400.6	.25262E+02	.26575E+00	.24695E+00
	451.3	.28454E+02	.27765E+00	.25029E+00
	500.0	.31527E+02	.29216E+00	.25319E+00
40.0	5.0	.32440E-01	.87979E-01	
	54.5	.35353E+00	.13378E+00	.13969E+00
	104.0	.67470E+00	.17839E+00	.15494E+00
	153.6	.99630E+00	.17419E+00	.16423E+00
	202.9	.13165E+01	.18006E+00	.17092E+00
	252.5	.16384E+01	.18935E+00	.17621E+00
	301.9	.19589E+01	.19502E+00	.18056E+00
	351.1	.22781E+01	.20181E+00	.18425E+00
	400.6	.25993E+01	.20773E+00	.18750E+00
	451.3	.29278E+01	.21935E+00	.19044E+00
	500.0	.32440E+01	.23034E+00	.19298E+00

Appendix H

Dynamic Tension Tabular Data for 58315 Estane

VISCOANALYSEUR TO :

METRAVIB
instruments

MEASUREMENT FILE........................ MVESTT1

DATE.................................... 3/ 31/ 95

SAMPLE REFERENCE........................ 58315 ESTANE

TEST PERFORMED IN : TRACTION COMPRESSION

SAMPLE FEATURES :

- SHAPE................................		PARALLELEPIPEDIC
- HEIGHT...............................	5.94	mm
- THICKNESS............................	4.04	mm
- WIDTH................................	4.15	mm

MEASUREMENT CONDITIONS :

- SCANNING IN TEMPERATURE..............	-40.0 - 39.9	oC
- SCANNING IN FREQUENCY................	5.0 - 500.0	HERTZ
- REGULATION IN DISPLACEMENT...........	5.0	MICRON
- PRESTRAIN REGULATION.................		NO

REMARKS :

TEST PERFORMED BY :

SERVICE :

SAMPLE REFERENCE........................ 58315 ESTANE

TEMPERATURE NUMBER.................... 1

- STARTING TEMPERATURE................ 24.7 oC
- VARIATION RATE OF TEMPERATURE....... 5.0 oC/mn
- STABILIZATION TIME IN TEMPERATURE... 15 mn
- FINAL TEMPERATURE................... -40.0 oC

No	FREQUENCY HERTZ	E' N/m2	E" N/m2	E N/m2	TAN. DELTA
1	5.0	.133E+10	.187E+09	.134E+10	.141
2	54.5	.160E+10	.166E+09	.161E+10	.104
3	104.0	.166E+10	.174E+09	.167E+10	.105
4	153.6	.170E+10	.178E+09	.171E+10	.105
5	202.9	.172E+10	.172E+09	.173E+10	.995E-01
6	252.5	.174E+10	.176E+09	.175E+10	.101
7	301.9	.178E+10	.183E+09	.179E+10	.103
8	351.1	.178E+10	.175E+09	.179E+10	.982E-01
9	400.6	.171E+10	.182E+09	.172E+10	.106
10	451.3	.177E+10	.179E+09	.177E+10	.102
11	500.0	.176E+10	.178E+09	.177E+10	.101

SAMPLE REFERENCE......................... 58315 ESTANE

TEMPERATURE NUMBER..................... 2

- STARTING TEMPERATURE................. -40.0 oC
- VARIATION RATE OF TEMPERATURE....... 5.0 oC/mn
- STABILIZATION TIME IN TEMPERATURE... 15 mn
- FINAL TEMPERATURE.................... -29.9 oC

No	FREQUENCY HERTZ	E' N/m2	E" N/m2	E N/m2	TAN. DELTA
1	5.0	.574E+09	.164E+09	.597E+09	.286
2	54.5	.834E+09	.200E+09	.858E+09	.240
3	104.0	.910E+09	.213E+09	.934E+09	.234
4	153.6	.956E+09	.220E+09	.981E+09	.230
5	202.9	.983E+09	.220E+09	.101E+10	.224
6	252.5	.102E+10	.228E+09	.104E+10	.225
7	301.9	.104E+10	.226E+09	.107E+10	.216
8	351.1	.104E+10	.227E+09	.106E+10	.218
9	400.6	.102E+10	.228E+09	.104E+10	.224
10	451.3	.108E+10	.230E+09	.110E+10	.214
11	500.0	.107E+10	.232E+09	.109E+10	.217

SAMPLE REFERENCE........................ 58315 ESTANE

TEMPERATURE NUMBER.................... 3

- STARTING TEMPERATURE................. -29.9 oC
- VARIATION RATE OF TEMPERATURE....... 5.0 oC/mn
- STABILIZATION TIME IN TEMPERATURE... 15 mn
- FINAL TEMPERATURE.................... -20.1 oC

No	FREQUENCY HERTZ	E' N/m2	E" N/m2	E N/m2	TAN. DELTA
1	5.0	.244E+09	.820E+08	.258E+09	.336
2	54.5	.401E+09	.138E+09	.424E+09	.345
3	104.0	.462E+09	.159E+09	.489E+09	.345
4	153.6	.501E+09	.173E+09	.530E+09	.345
5	202.9	.523E+09	.180E+09	.553E+09	.344
6	252.5	.544E+09	.183E+09	.574E+09	.336
7	301.9	.552E+09	.185E+09	.582E+09	.335
8	351.1	.574E+09	.191E+09	.605E+09	.332
9	400.6	.574E+09	.192E+09	.605E+09	.334
10	451.3	.579E+09	.195E+09	.611E+09	.336
11	500.0	.595E+09	.200E+09	.628E+09	.335

SAMPLE REFERENCE........................ 58315 ESTANE

TEMPERATURE NUMBER.................... 4

- STARTING TEMPERATURE................. -20.1 oC
- VARIATION RATE OF TEMPERATURE....... 5.0 oC/mn
- STABILIZATION TIME IN TEMPERATURE... 15 mn
- FINAL TEMPERATURE................... -10.2 oC

No	FREQUENCY HERTZ	E' N/m2	E" N/m2	E N/m2	TAN. DELTA
1	5.0	.133E+09	.364E+08	.138E+09	.274
2	54.5	.208E+09	.738E+08	.220E+09	.355
3	104.0	.239E+09	.903E+08	.255E+09	.378
4	153.6	.259E+09	.102E+09	.278E+09	.395
5	202.9	.272E+09	.105E+09	.291E+09	.388
6	252.5	.289E+09	.113E+09	.310E+09	.389
7	301.9	.298E+09	.117E+09	.320E+09	.392
8	351.1	.306E+09	.121E+09	.329E+09	.395
9	400.6	.313E+09	.124E+09	.336E+09	.397
10	451.3	.316E+09	.127E+09	.340E+09	.401
11	500.0	.317E+09	.130E+09	.343E+09	.409

SAMPLE REFERENCE........................ 58315 ESTANE

TEMPERATURE NUMBER.................... 5

- STARTING TEMPERATURE................ -10.2 oC
- VARIATION RATE OF TEMPERATURE....... 5.0 oC/mn
- STABILIZATION TIME IN TEMPERATURE... 15 mn
- FINAL TEMPERATURE................... .0 oC

No	FREQUENCY HERTZ	E' N/m2	E" N/m2	E N/m2	TAN. DELTA
1	5.0	.914E+08	.174E+08	.931E+08	.190
2	54.5	.126E+09	.363E+08	.131E+09	.289
3	104.0	.139E+09	.455E+08	.146E+09	.328
4	153.6	.150E+09	.519E+08	.159E+09	.346
5	202.9	.160E+09	.566E+08	.170E+09	.353
6	252.5	.168E+09	.612E+08	.179E+09	.363
7	301.9	.172E+09	.635E+08	.183E+09	.369
8	351.1	.177E+09	.669E+08	.190E+09	.377
9	400.6	.183E+09	.701E+08	.196E+09	.384
10	451.3	.186E+09	.729E+08	.200E+09	.393
11	500.0	.184E+09	.750E+08	.199E+09	.408

SAMPLE REFERENCE........................ 58315 ESTANE

TEMPERATURE NUMBER.................... 6

- STARTING TEMPERATURE................. .0 oC
- VARIATION RATE OF TEMPERATURE....... 5.0 oC/mn
- STABILIZATION TIME IN TEMPERATURE... 15 mn
- FINAL TEMPERATURE................... 10.1 oC

No	FREQUENCY HERTZ	E' N/m2	E" N/m2	E N/m2	TAN. DELTA
1	5.0	.729E+08	.973E+07	.735E+08	.134
2	54.5	.914E+08	.194E+08	.934E+08	.212
3	104.0	.989E+08	.254E+08	.102E+09	.256
4	153.6	.105E+09	.282E+08	.109E+09	.269
5	202.9	.110E+09	.308E+08	.114E+09	.279
6	252.5	.113E+09	.328E+08	.118E+09	.290
7	301.9	.115E+09	.341E+08	.120E+09	.296
8	351.1	.119E+09	.368E+08	.124E+09	.310
9	400.6	.122E+09	.391E+08	.128E+09	.321
10	451.3	.123E+09	.408E+08	.129E+09	.332
11	500.0	.121E+09	.431E+08	.129E+09	.356

SAMPLE REFERENCE........................ 58315 ESTANE

TEMPERATURE NUMBER.................... 7

- STARTING TEMPERATURE................. 10.1 oC
- VARIATION RATE OF TEMPERATURE....... 5.0 oC/mn
- STABILIZATION TIME IN TEMPERATURE... 15 mn
- FINAL TEMPERATURE.................... 20.0 oC

No	FREQUENCY HERTZ	E' N/m2	E" N/m2	E N/m2	TAN. DELTA
1	5.0	.630E+08	.636E+07	.633E+08	.101
2	54.5	.744E+08	.118E+08	.753E+08	.159
3	104.0	.793E+08	.152E+08	.808E+08	.191
4	153.6	.824E+08	.170E+08	.841E+08	.206
5	202.9	.853E+08	.182E+08	.872E+08	.213
6	252.5	.872E+08	.194E+08	.893E+08	.223
7	301.9	.888E+08	.205E+08	.911E+08	.231
8	351.1	.903E+08	.218E+08	.929E+08	.242
9	400.6	.910E+08	.226E+08	.938E+08	.249
10	451.3	.912E+08	.239E+08	.943E+08	.262
11	500.0	.885E+08	.257E+08	.921E+08	.290

SAMPLE REFERENCE........................ 58315 ESTANE

TEMPERATURE NUMBER.................... 8

- STARTING TEMPERATURE................ 20.0 oC
- VARIATION RATE OF TEMPERATURE....... 5.0 oC/mn
- STABILIZATION TIME IN TEMPERATURE... 15 mn
- FINAL TEMPERATURE.................. 30.0 oC

No	FREQUENCY HERTZ	E' N/m2	E" N/m2	E N/m2	TAN. DELTA
1	5.0	.542E+08	.432E+07	.544E+08	.796E-01
2	54.5	.615E+08	.748E+07	.620E+08	.122
3	104.0	.640E+08	.925E+07	.647E+08	.145
4	153.6	.659E+08	.105E+08	.668E+08	.159
5	202.9	.676E+08	.109E+08	.685E+08	.162
6	252.5	.688E+08	.117E+08	.698E+08	.170
7	301.9	.698E+08	.123E+08	.708E+08	.177
8	351.1	.706E+08	.131E+08	.718E+08	.185
9	400.6	.708E+08	.135E+08	.721E+08	.190
10	451.3	.699E+08	.144E+08	.714E+08	.205
11	500.0	.666E+08	.156E+08	.684E+08	.235

SAMPLE REFERENCE........................ 58315 ESTANE

TEMPERATURE NUMBER.................... 9

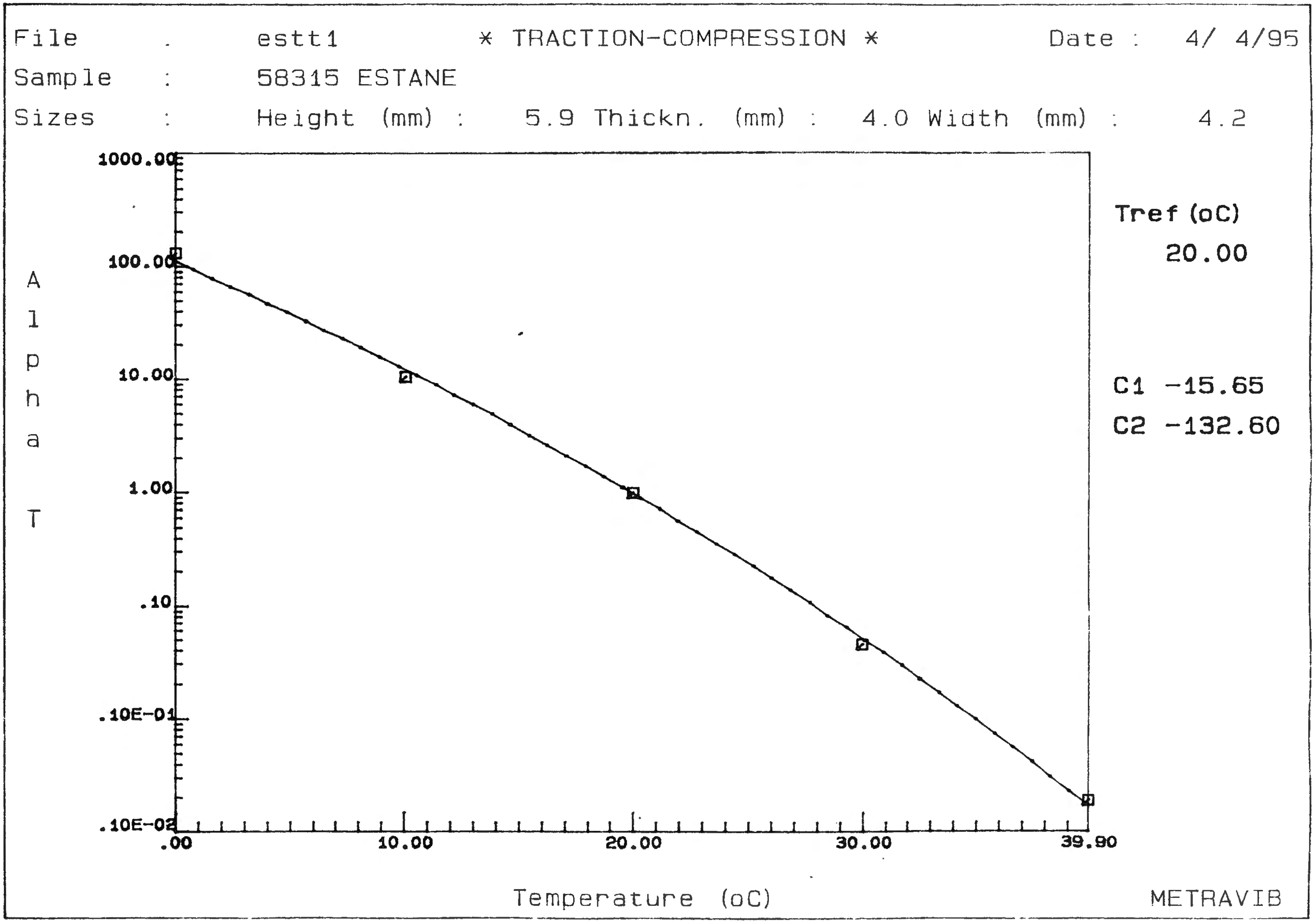
- STARTING TEMPERATURE................ 30.0 oC
- VARIATION RATE OF TEMPERATURE....... 5.0 oC/mn
- STABILIZATION TIME IN TEMPERATURE... 15 mn
- FINAL TEMPERATURE................... 39.9 oC

No	FREQUENCY HERTZ	E' N/m2	E" N/m2	E N/m2	TAN. DELTA
1	5.0	.479E+08	.343E+07	.480E+08	.716E-01
2	54.5	.534E+08	.551E+07	.537E+08	.103
3	104.0	.547E+08	.668E+07	.551E+08	.122
4	153.6	.562E+08	.760E+07	.567E+08	.135
5	202.9	.573E+08	.778E+07	.579E+08	.136
6	252.5	.581E+08	.830E+07	.587E+08	.143
7	301.9	.587E+08	.865E+07	.594E+08	.147
8	351.1	.590E+08	.904E+07	.597E+08	.153
9	400.6	.590E+08	.944E+07	.597E+08	.160
10	451.3	.575E+08	.994E+07	.583E+08	.173
11	500.0	.537E+08	.109E+08	.548E+08	.203

Appendix I

E' Master Curve and Shift Factor Tabular Data for 58315 Estane

I-2



File . estt1 * TRACTION-COMPRESSION * Date : 4/ 4/95
Sample : 58315 ESTANE
Sizes : Height (mm) : 5.9 Thickn. (mm) : 4.0 Width (mm) : 4.2
Tref (oC)
20.00
C1 -15.65
C2 -132.60
1000.00
100.00
10.00
1.00
.10
.10E-01
.10E-02
A l p h a T
.00
10.00
20.00
30.00
39.90
Temperature (oC)
METRAVIB

File : estt1 * TRACTION-COMPRESSION * Date : 4/ 4/95

Sample : 58315 ESTANE

Sizes : Height (mm) : 5.94
Thickn. (mm) : 4.04
Width (mm) : 4.15

REGULATION : DYNAMIC (1E-6M) : 5.00
STATIC (1E-6M) : NO

REFERENCE TEMPERATURE (OC) : 20.00

WLF COEFFICIENTS C1 AND C2 : -.15650E+02 -.13260E+03

TEMPERATURE (OC)	ALPHA(T) MEA.	ALPHA(T) CAL.
.0	.13268E+03	.11247E+03
10.1	.10564E+02	.12224E+02
20.0	.10000E+01	.10000E+01
30.0	.45776E-01	.52912E-01
39.9	.19375E-02	.17248E-02

T(OC)	F(HZ)	F*ALPHA(T) (HZ)	E' (N M2) MEA.	E (N/M2) CAL.
20.0	351.1	.35112E+03	.90317E+08	.90255E+08
	400.6	.40064E+03	.91038E+08	.91590E+08
	451.3	.45126E+03	.91174E+08	.92831E+08
	500.0	.50000E+03	.88482E+08	.93929E+08
30.0	5.0	.22888E+00	.52398E+08	.52099E+08
	54.5	.24943E+01	.59502E+08	.59716E+08
	104.0	.47604E+01	.61907E+08	.62282E+08
	153.6	.70294E+01	.63766E+08	.63968E+08
	202.9	.92889E+01	.65363E+08	.65246E+08
	252.5	.11559E+02	.66504E+08	.66293E+08
	301.9	.13821E+02	.67463E+08	.67181E+08
	351.1	.16073E+02	.68284E+08	.67954E+08
	400.6	.18340E+02	.68452E+08	.68647E+08
	451.3	.20657E+02	.67620E+08	.69288E+08
	500.0	.22888E+02	.64402E+08	.69852E+08
39.9	5.0	.96874E-02	.44828E+08	
	54.5	.10557E+00	.49988E+08	.50087E+08
	104.0	.20149E+00	.51246E+08	.51755E+08
	153.6	.29753E+00	.52651E+08	.52822E+08
	202.9	.39316E+00	.53700E+08	.53617E+08
	252.5	.48926E+00	.54447E+08	.54261E+08
	301.9	.58499E+00	.55014E+08	.54800E+08
	351.1	.68030E+00	.55216E+08	.55266E+08
	400.6	.77624E+00	.55202E+08	.55681E+08
	451.3	.87432E+00	.53812E+08	.56062E+08
	500.0	.96874E+00	.50281E+08	.56395E+08

File : estt1 * TRACTION-COMPRESSION * Date : 4/ 4/95

Sample : 58315 ESTANE

Sizes : Height (mm) : 5.94
Thickn. (mm) : 4.04
Width (mm) : 4.15

REGULATION : DYNAMIC (1E-6M) : 5.00
STATIC (1E-6M) : NO

** MASTER CURVE **

FERENCE TEMPERATURE : 20.00 oC

POLYNOMIAL COEFFICIENTS (LOG10-LOG10 IN INCREASING ORDER) :

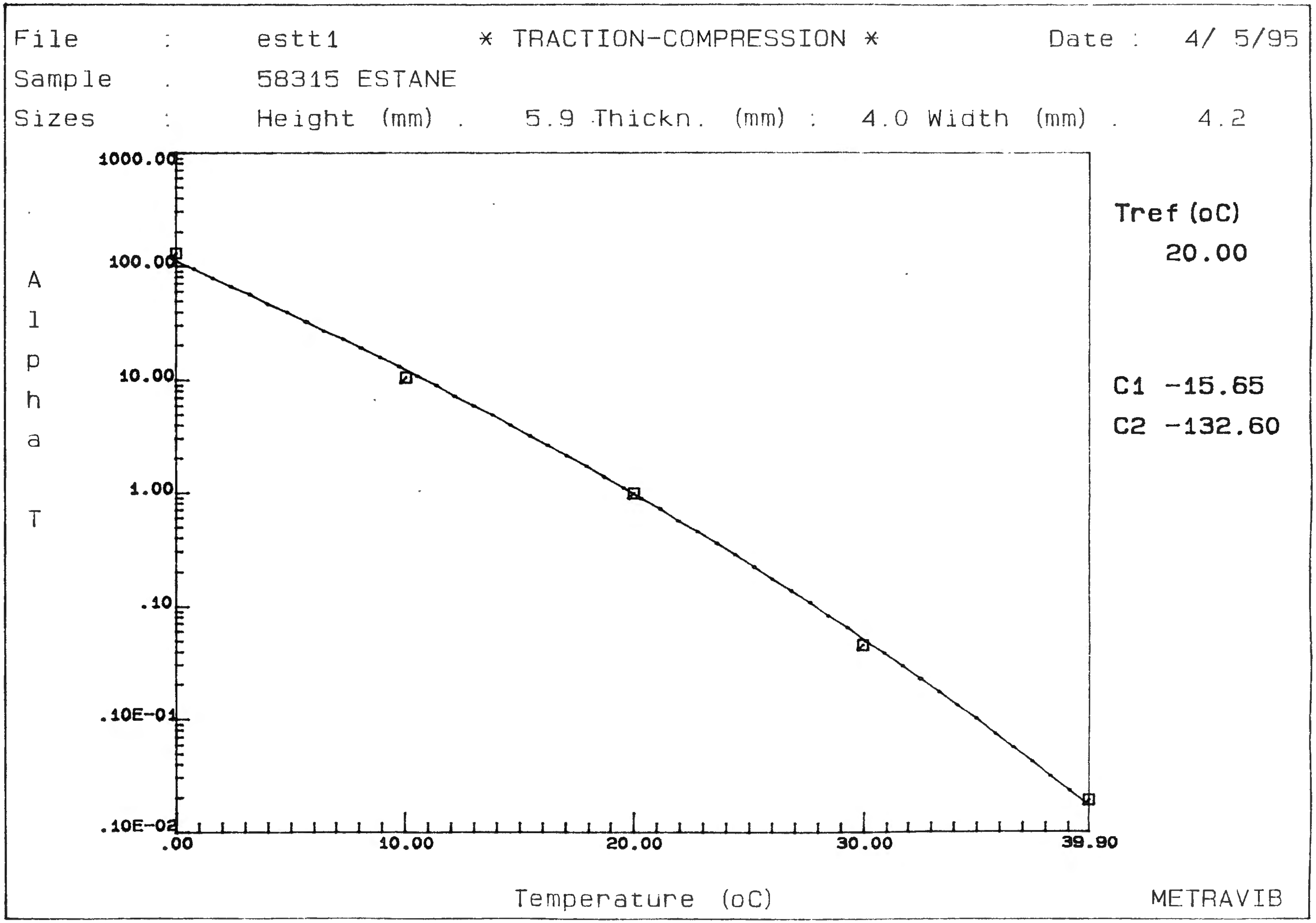
.77520E+01 * .58198E-01 * .55917E-02 * .95919E-03 * .77131E-04 *

T(OC)	F(HZ)	F*ALPHA(T) (HZ)	E' (N/M2) MEA.	E' (N/M2) CAL.
.0	5.0	.66338E+03	.98118E+08	.97102E+08
	54.5	.72295E+04	.13486E+09	.13556E+09
	104.0	.13797E+05	.14865E+09	.15118E+09
	153.6	.20374E+05	.16120E+09	.16218E+09
	202.9	.26923E+05	.17212E+09	.17089E+09
	252.5	.33504E+05	.18059E+09	.17828E+09
	301.9	.40059E+05	.18467E+09	.18472E+09
	351.1	.46586E+05	.19043E+09	.19046E+09
	400.6	.53156E+05	.19589E+09	.19571E+09
	451.3	.59872E+05	.19930E+09	.20065E+09
	500.0	.66338E+05	.19727E+09	
10.1	5.0	.52820E+02	.75430E+08	.74901E+08
	54.5	.57563E+03	.94597E+08	.95482E+08
	104.0	.10986E+04	.10237E+09	.10334E+09
	153.6	.16222E+04	.10844E+09	.10874E+09
	202.9	.21437E+04	.11409E+09	.11296E+09
	252.5	.26677E+04	.11721E+09	.11649E+09
	301.9	.31896E+04	.11890E+09	.11953E+09
	351.1	.37093E+04	.12303E+09	.12222E+09
	400.6	.42324E+04	.12624E+09	.12466E+09
	451.3	.47672E+04	.12699E+09	.12695E+09
	500.0	.52820E+04	.12539E+09	.12897E+09
20.0	5.0	.50000E+01	.62998E+08	.62488E+08
	54.5	.54490E+02	.74367E+08	.75106E+08
	104.0	.10399E+03	.79316E+08	.79675E+08
	153.6	.15356E+03	.82354E+08	.82755E+08
	202.9	.20292E+03	.85327E+08	.85126E+08
	252.5	.25253E+03	.87181E+08	.87094E+08
	301.9	.30193E+03	.88767E+08	.88777E+08

Appendix J

Tan Delta Master Curve and Shift Factor Tabular Data for 58315 Estane

J-2


File : estt1
* TRACTION-COMPRESSION *
Date : 4/ 5/95
Sample . 58315 ESTANE
Sizes : Height (mm) . 5.9 Thickn. (mm) : 4.0 Width (mm) . 4.2
1000.00
100.00
10.00
1.00
.10
.10E-01
.10E-02
Alpha T
.00
10.00
20.00
30.00
39.90
Temperature (oC)
Tref (oC)
20.00
C1 -15.65
C2 -132.60
METRAVIB

File : estt1 * TRACTION-COMPRESSION * Date : 4/ 5/95

Sample : 58315 ESTANE

Sizes : Height (mm) : 5.94
Thickn. (mm) : 4.04
Width (mm) : 4.15

REGULATION : DYNAMIC (1E-6M) : 5.00
STATIC (1E-6M) : NO

REFERENCE TEMPERATURE (OC) : 20.00

WLF COEFFICIENTS C1 AND C2 : -.15650E+02 -.13260E+03

TEMPERATURE (OC)	ALPHA(T) MEA.	ALPHA(T) CAL.
.0	.13268E+03	.11247E+03
10.1	.10564E+02	.12224E+02
20.0	.10000E+01	.10000E+01
30.0	.45776E-01	.52912E-01
39.9	.19375E-02	.17248E-02

File : estt1 * TRACTION-COMPRESSION * Date : 4/ 5/95

Sample : 58315 ESTANE

Sizes : Height (mm) : 5.94
Thickn. (mm) : 4.04
Width (mm) : 4.15

REGULATION : DYNAMIC (1E-6M) : 5.00
STATIC (1E-6M) : NO

** MASTER CURVE **

FERENCE TEMPERATURE : 20.00 oC

POLYNOMIAL COEFFICIENTS (LOG10-LOG10 IN INCREASING ORDER) :

-.86921E+00 * .65675E-01 * -.10771E-01 * .10710E-01 * -.15202E-02 *

T(OC)	F(HZ)	F*ALPHA(T) (HZ)	TAN DELTA MEA.	TAN DELTA CAL.
.0	5.0	.66338E+03	.19047E+00	.23692E+00
	54.5	.72295E+04	.28856E+00	.31783E+00
	104.0	.13797E+05	.32846E+00	.33997E+00
	153.6	.20374E+05	.34587E+00	.35204E+00
	202.9	.26923E+05	.35265E+00	.35974E+00
	252.5	.33504E+05	.36348E+00	.36509E+00
	301.9	.40059E+05	.36884E+00	.36893E+00
	351.1	.46586E+05	.37699E+00	.37175E+00
	400.6	.53156E+05	.38391E+00	.37387E+00
	451.3	.59872E+05	.39270E+00	
	500.0	.66338E+05	.40786E+00	
10.1	5.0	.52820E+02	.13353E+00	.17920E+00
	54.5	.57563E+03	.21227E+00	.23280E+00
	104.0	.10986E+04	.25639E+00	.25239E+00
	153.6	.16222E+04	.26950E+00	.26514E+00
	202.9	.21437E+04	.27930E+00	.27463E+00
	252.5	.26677E+04	.28974E+00	.28225E+00
	301.9	.31896E+04	.29646E+00	.28856E+00
	351.1	.37093E+04	.30992E+00	.29394E+00
	400.6	.42324E+04	.32072E+00	.29867E+00
	451.3	.47672E+04	.33229E+00	.30294E+00
	500.0	.52820E+04	.35580E+00	.30662E+00
20.0	5.0	.50000E+01	.10103E+00	.14953E+00
	54.5	.54490E+02	.15860E+00	.17972E+00
	104.0	.10399E+03	.19130E+00	.19150E+00
	153.6	.15356E+03	.20623E+00	.19957E+00
	202.9	.20292E+03	.21303E+00	.20581E+00
	252.5	.25253E+03	.22291E+00	.21099E+00
	301.9	.30193E+03	.23123E+00	.21541E+00

T(OC)	F(HZ)	F*ALPHA(T) (HZ)	TAN DELTA MEA.	TAN DELTA CAL.
20.0	351.1	.35112E+03	.24172E+00	.21928E+00
	400.6	.40064E+03	.24863E+00	.22276E+00
	451.3	.45126E+03	.26239E+00	.22598E+00
	500.0	.50000E+03	.29010E+00	.22882E+00
30.0	5.0	.22888E+00	.79647E-01	.12057E+00
	54.5	.24943E+01	.12153E+00	.14315E+00
	104.0	.47604E+01	.14451E+00	.14906E+00
	153.6	.70294E+01	.15880E+00	.15290E+00
	202.9	.92889E+01	.16185E+00	.15583E+00
	252.5	.11559E+02	.17048E+00	.15825E+00
	301.9	.13821E+02	.17655E+00	.16033E+00
	351.1	.16073E+02	.18506E+00	.16215E+00
	400.6	.18340E+02	.19043E+00	.16379E+00
	451.3	.20657E+02	.20535E+00	.16533E+00
	500.0	.22888E+02	.23453E+00	.16669E+00
39.9	5.0	.96874E-02	.71568E-01	
	54.5	.10557E+00	.10317E+00	.11093E+00
	104.0	.20149E+00	.12210E+00	.11910E+00
	153.6	.29753E+00	.13520E+00	.12347E+00
	202.9	.39316E+00	.13572E+00	.12637E+00
	252.5	.48926E+00	.14270E+00	.12854E+00
	301.9	.58499E+00	.14723E+00	.13025E+00
	351.1	.68030E+00	.15335E+00	.13166E+00
	400.6	.77624E+00	.16011E+00	.13287E+00
	451.3	.87432E+00	.17302E+00	.13394E+00
	500.0	.96874E+00	.20327E+00	.13486E+00

REFERENCES

1. John D. Ferry, *Viscoelastic Properties of Polymers*, 3rd Ed., John Wiley & Sons, 1980, Chap. 11.

2. Lawrence E. Nielson, *Mechanical Properties of Polymers and Composites*, Vol 1, Marcel Dekker, pages 79-87

3. *WLF Software Users Manual*, Metravib Instrument Company, 1989.

INITIAL DISTRIBUTION LIST

Addressee	No. of Copies
Defense Technical Information Center	2